JOURNAL

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OF THE INSTITUTION OF ELECTRICAL ENGINEERS

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THE ROLE OF THE CONSULTING ENGINEER

CONSULTING ENGINEERING IS A PROFESSION WHICH started considerably more than a hundred years ago. In the early days the profession was confined mainly to civil engineering (particularly water, sewage and harbour works), with a gradually increasing amount of mechanical and, later, electrical engineering. Consulting engineers were often men of outstanding knowledge, who advised largely as individuals: the names of Blythe, Rendel, Wolfe Barry, Coode, Fox, Mott, Kennedy, Merz and Preece are examples of such men. As the scope of engineering works widened, partnerships became more general, involving the employment of appreciable numbers of staff. During the past 25 years the scale of engineering projects has increased enormously, and this in turn has augmented the size of some firms of consulting engineers, although there remains the need in many classes of work for the small firm or single consultant. Whether a long-established firm is large or small, partners and staff form an integrated team rather than a mere assembly of experts. Modern developments have, in fact, tended to divide consulting engineers into three categories. First, there are, and always have been from the beginning of the profession, individuals who are conversant with unusual technical problems on which they have specialized knowledge. Secondly, there are firms of small or medium size particularly concerned with some fairly specialized function, such, for instance, as electrical installations in industrial concerns and large buildings. Lastly, there are a comparatively few large firms, with very considerable staffs capable of dealing with the bigger schemes, and employing high-grade specialists in all branches of their work; it is mostly these firms that are concerned with work oversea.

Along with these changes there has been a growth in the traditions of the profession and a definition of the code of ethics which governs it. This code is defined in the Bye-laws of The Institution as well as in those of The Institution of Civil Engineers, and in the Rules of the Association of Consulting Engineers, which was formed in 1913. Those who practise consulting engineering normally undertake the design and supervision of construction of engineering works and are remunerated entirely by fees from their client, for whom they act in a fiduciary capacity. They keep themselves absolutely independent of any manufacturing and contracting interests and have built up a tradition of professional integrity on a par with the much older professions of medicine and the law. Professional practice closely parallels that of architecture. The special status achieved by consulting engineers was early recognized by the oldest of the three major engineering Institutions, namely The Institution of Civil Engineers, and it has since been recognized by our own Institution.

There is a variety of circumstances in which the services of a consulting engineer may become desirable. In the past the most usual was doubtless sheer lack of scientific and engineering knowledge on the part of the client, who had, therefore, to call in the impartial expert. Although such conditions often still prevail, and although the need for impartiality will always remain, there are new factors which frequently govern the decision whether or not to seek the assistance of a consultant. A client may have expert scientific and engineering knowledge but may be faced with a new project so large that it is beyond the capacity of his operating organization. In such cases the choice lies between building up special development or construction departments—probably employing many technical staff—to handle the new development, and entrusting this task to one or more firms of consulting engineers. If the first alternative is

adopted it may not be possible to keep the new staff fully occupied after the project has been completed, and then the method is likely to be uneconomic. This alternative is at present particularly undesirable, owing to increasing shortage of both technologists and technicians. A firm of consulting engineers can, on the other hand, maintain a reasonably good load factor if their business is extensive and they are dealing with many new developments. The duties of a consulting engineer may include reporting on the feasibility and economics of the project; preparing general layouts, designs and specifications; calling for competitive tenders; adjudicating on tenders and reporting to their client; placing orders on behalf of their client; examining and approving contractors' designs and drawings; inspecting and testing at the works during manufacture; supervising construction on site; and witnessing taking-over tests. In addition, payments to contractors would be certified as they became due. Thus, if fully used, a consulting engineer relieves a client of all major development work and enables the client's staff to concentrate on their primary duty of commercial operation.

This particularly applies to clients with small- or moderate-size organizations. On the other hand, where organizations are large and therefore more capable of handling their development work, it may often be found difficult to ensure sufficient personal initiative and adequate freedom and encouragement in the adoption of new ideas and practices. Consulting engineers are, inherently, individualists and—whether or not individualism is wholly good—substantial advantage may be obtained by the employment of consulting engineers in parallel with the engineering departments of large organizations. Both parties may benefit by mutual contact and possibly by some degree of friendly competition.

There is another circumstance which may affect a decision to employ consulting engineers. Those firms that have an extensive practice, both in Great Britain and abroad, have a unique opportunity of studying and comparing technical practice in all parts of the world and of bringing to each particular problem a very wide range of knowledge. This may not otherwise be available to the client.

With the growth of public ownership in Great Britain very large organizations have been created, to which the above remarks may not apply, since such an organization may be conversant with technical development both in Great Britain and abroad. For these large public authorities there is, however, the national obligation to help our export trade; they have great opportunities to do this both by the development of new plant and equipment, for which there is a market abroad, and by the employment of consulting engineers. It is widely recognized that the consulting engineer can frequently act as the spearhead of our export drive, but this will not be possible unless he is adequately employed on home work. Oversea clients are unlikely to place value on the advice of consulting engineers who have not acquired knowledge, experience and reputation, based on work in their own country. Such considerations are being increasingly recognized by our major public authorities, who accept the fostering of exports as one of their national duties.

The connection of the consulting engineer with British export trade might seem to imply that contracts would always be placed with British contractors and would, therefore, involve a breach of the British consulting engineer's reputation for complete impartiality. This is not, however, necessary. Tenders cannot be recommended unless they are the most advantageous to the client, but British contractors know that they can rely, through British consulting engineers, on unambiguous specifications and impartial adjudication of their tenders. They can also rely on British consulting engineers acting fairly between the client and the contractor. So long as British plant and equipment are, in fact, the best, the British consulting engineer will ensure that the true merits of British tenders are properly presented to the oversea client.

In recent times there has been some controversy about the practice of obtaining "all-in" bids for complete projects. This practice received a certain amount of encouragement from manufacturers and contractors in the United States, where the expression "turn-key bid" was coined. An "all-in," or "turn-key," bid is an offer to design and complete a project, lock, stock and barrel, at a more-or-less lump-sum price, and such a comprehensive offer necessarily covers consulting and design services as well as manufacture and construction. An offer of this sort may be attractive to certain clients who are not themselves able to prepare detailed specifications or wish to avoid the trouble of doing so, and who are, perhaps, unaware of the more normal practice of employing consulting engineers.

At one time the practice seemed to be extending, and, in order to avoid the risk of important work being lost to Great Britain, British consultants had to consider the possibility of working with contractors, or groups of contractors, to assist them in design and other work necessary both for the purpose of preparing an "all-in" bid and in carrying through the work if the bid were accepted. Although such unusual employment of consulting engineers can be contemplated in certain circumstances, it is widely felt that such a system is not usually in the interests of the client and that the client-consultant-contractor relationship, based on the normal practice of obtaining competitive tenders with the

assistance and guidance of a consulting engineer responsible for design, is likely to produce a cheaper and better job. Oversea clients are apt to forget that the services performed by a consulting engineer are necessary in any event; if not provided in the normal way, they will have to be in some other manner and will consequently have to be paid for in an increased contract price. If, in submitting competitive "all-in" bids, a considerable number of contractors (or groups of contractors) are involved in working out designs, only one of which will eventually be accepted, it is obvious that in the long run the clients will have to pay for such inflated costs.

The controversy about this matter and its bearing on the ethical code of consulting engineers is now decreasing, largely because the use of the "all-in" bid appears to be diminishing. Clients have not always had satisfactory experience of "all-in" bids, and probably, even in underdeveloped countries, there is increasing understanding of the normal method of employing consulting engineers and the benefits obtainable thereby. The International Bank itself does not appear to regard "all-in" bids with favour, and it is anticipated that the Bank's powerful influence will, in future, tend to discourage the practice.

The work of British consulting engineers abroad is important not merely in regard to British export trade: the experience and knowledge which have been accumulated over the past century or more do allow the profession to make a valuable contribution to the vast problem of raising the standard of living in the underdeveloped areas of Asia, Africa and elsewhere. Many of the world's problems are due to the existence of widely differing levels of culture and standards of living, and until these differences can be reduced to more reasonable proportions they must remain a constant threat to world peace. It is unquestionably a paramount duty of all highly developed nations, such as Great Britain, to help in raising the standards of living and in spreading peace-promoting conditions amongst those peoples at present living at bare subsistence levels.

This great task is being facilitated by the International Bank and by other international activities, including the Colombo Plan and the U.S.A. Point IV Scheme. The consulting engineer has a special part to play in such activities. It is not enough merely to provide the necessary finance; plans for large-scale engineering developments have to be prepared, with assistance and supervision in the carrying through of the projects. It would seem that the future will demand that British consulting engineers carry out an increasing proportion of oversea work. This is both a duty and a necessity. It is a duty in the interests of world peace and it is a necessity because Great Britain has to live by the exchanges of foreign trade. For some countries imports and exports may be merely a desirable margin in the business of getting a living, but for us they are the means of life.

The British Nuclear Energy Conference

IN the light of recent rapid developments in the technology of nuclear energy, and the increasing demand for a common ground between scientists and engineers where these developments can be discussed, an organization has been formed by The Institutions of Civil, Mechanical, Electrical, and Chemical Engineers, and The Institute of Physics, to satisfy this need. This will be known as the British Nuclear Energy Conference, whose affairs will be managed by a Board consisting of three representatives from each of these societies. The Chairman is Sir Christopher Hinton, and Sir John Cockcroft is one of its distinguished members. The Secretary is Mr. Alexander McDonald (Secretary of The Institution of Civil Engineers, Great George Street, London, S.W.1).

The five societies will arrange for the presentation of papers dealing with nuclear-energy subjects, and all members of the societies will be able to attend and take part in the discussions. The Conference will publish a journal about four times a year containing records of the papers, discussions, symposia and conventions conducted by the Board. This journal will be offered for sale.

The Board proposes to hold its inaugural meeting in the autumn of 1955, when a symposium of lectures will be delivered on the technology of nuclear energy and its applications. National and international conventions will be promoted from time to time, and the Board will arrange for British participation in international meetings.

The initial expenses will be met by the five professional societies, although the Conference should be self-supporting once it is fully established.

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The Radio Section discuss

COLOUR TELEVISION

On the 25th October, 1954, Mr. E. P. Wethey, B.Sc., Chief Engineer of Kolster-Brandes, opened a discussion on "Whether Compatibility is necessary for a Colour-Television System in Great Britain" at a meeting of the Radio Section. A summary of his remarks, and of the subsequent discussion, appears below.

MR. E. P. WETHEY began by defining compatibility as the ability of black-and-white receivers to receive colour-television transmissions, and reverse compatibility as the ability of colour receivers to use black-and-white transmissions.

For the viewer using a black-and-white receiver compatibility is desirable, provided that no degradation of the picture takes place. It might be possible to allow a slight modification enabling this to be done, but in view of the fact that nearly four million receivers are now in use and that this number will probably be doubled by the time colour programmes begin, even a small alteration to these sets would involve considerable work. For the viewer using a colour-television receiver, reverse compatibility is desirable, provided that there is no undue increase in cost of the colour set and that good picture quality and scope for development are retained.

It is possible that the introduction of a colour-television system will be the last chance for a revision of television standards for some considerable time, and future black-and-white and colour-television transmissions should be considered together for any new system.

Mr. Wethey thought it unlikely that a large proportion of programmes would be in colour at the start, and at present the use of colour receivers to display black-and-white pictures is uneconomic and is a stringent test of the colour receiver. Whatever system is chosen, the principle of separating luminance and chrominance appears to be a fundamental advantage. Using a 405-line system, a modification of the American N.T.S.C. system is a possibility, although the black-and-white receivers at present in use suffer in varying degrees from "buzz" on sound, dot patterning and ripple, owing to the necessity for asynchronous working. If the colour information is transmitted outside the band, e.g. on the high-frequency side of the vision carrier, these disadvantages are largely removed, but the channel spacing becomes difficult, as allocations have already been made in Bands* I and III allowing only a 5 Mc/s channel width. A more acceptable possibility would be to use a 625-line system with the colour information close to the video band and transmissions in Band IV. The problems involved in receivers and transmitters designed for this band should have been greatly minimized by the time colour television is available, and the possibility remains that the development of a standard conversion system will then have reached such a stage that it is satisfactory for the conversion of these signals to the present 405-line system, which could then be retransmitted in Bands I and III.

In the discussion which followed Mr. Wethey's remarks, the views were sharply divided as to whether compatibility was a necessary and desirable feature of a colour-television system in Great Britain, although it was generally agreed that a colour-television system was desirable from the entertainment aspect. A dissenting view was that full use had not yet been made of the present 405-line monochrome system, and the further opinion was expressed that colour television was not desirable for every type of programme. It was also pointed out that some monochrome sets in use at present in Great Britain would require modification to be capable of reproducing satisfactory pictures from a compatible transmission.

One speaker who had had wide experience of compatible colour-television systems in the United States maintained that the cost of introducing an incompatible 625-line colour television service in Band IV would be prohibitive; in addition, the difficulties associated with such a system at the outset, particularly with regard to the manufacture of sets and the transmission of programmes, would be almost insurmountable. It was admitted that black-and-white receivers in use on the N.T.S.C. compatible system suffered in varying degrees from asynchronous working, as Mr. Wethey had pointed out, but the system as a whole was capable of giving good service and entertainment to the general public.

The introduction of a colour-television service with widespread coverage of Great Britain was not considered to be practical for at least two years and possibly for as long as five years. The development of an entirely new compatible system was not thought to be very likely, and in view of this and the possible difficulties associated with the N.T.S.C. system if applied to Great Britain, some contributors thought that a non-compatible system would be more widely acceptable to the British public. It was pointed out, however, that an increase in the cost of distribution of programmes by cable and radio link would follow on the adoption of an incompatible system, and in addition, the problem of future overcrowding of available bands should be borne in mind before an incompatible colour system was adopted. The question of the cost of transmitting and receiving equipment for the bands available was also raised, and in this respect one speaker thought that colour-television transmissions should not be placed in Bands I and III, but that the whole scheme should be shelved until future technical development made compatible systems possible in Bands IV and V.

The advantages of a 625-line system were touched upon when it was suggested that this would greatly increase the possibility of programme exchange with Continental countries and, in addition, better colour reproduction would be obtained. This point was not generally conceded, and an opposing view maintained that the N.T.S.C. system provided good colour pictures of a minimum acceptable standard, and the advantage of the lower overall cost of a compatible system was also mentioned. It was recognized that differences between ways of life in Europe and the United States must be borne in mind, and it was pointed out that the percentage of programme time devoted to colour transmissions in the United States was still low. With the smaller amount of capital available for television development in Great Britain, it was agreed that a close review of compatible and incompatible systems must be made before a final decision between them was reached.

* The broadcast frequency bands are:
Band I: 41–68 Mc/s.
Band II: 87·5–100 Mc/s.
Band III: 174–216 Mc/s.
Band IV: 470–585 Mc/s.
Band V: 610–960 Mc/s.

SOUND BROADCASTING IN NORTH AMERICA

R. H. TANNER, T.D., B.Sc.(Eng.), *Member*

In this article, Mr. Tanner, of the Northern Electric Co., Canada, reviews briefly the state of sound broadcasting on the North American continent, and shows how it has been influenced by the history of its development.

FOR many reasons—political, geographical and technical—sound broadcasting on the North American continent has developed along very different lines from those which have been followed in Great Britain, or for that matter in Europe as a whole. This article seeks to describe only the technical differences resulting from this divergence, but in order to do so with clarity, it first outlines the historical background of broadcasting in the great area under discussion.

Historical Background

The United States.—As in so many other countries, the first broadcasting station to open in the United States was owned by a large electrical engineering concern, in this case the Westinghouse Electric Corporation. The station, KDKA, began operating on the 2nd November, 1920, under licence from the Secretary of Commerce, Mr. Herbert Hoover, who had assumed the responsibility of controlling this new field in the absence of any specific legislation on the matter. By 1922 there were 30 licensed broadcasting stations in operation, and by 1924 there were over 500. By comparison, the number of European stations listed in the Copenhagen wavelength allocation in 1948 was only 320. Since the North American frequency allotments set aside only the medium-wave band for broadcasting, reserving the long-wave band for other services, it is obvious that the available channels were soon filled many times over, and the principle of channel sharing so unwillingly adopted at European conferences was established almost irrevocably at a very early date. Under the circumstances, it is hardly surprising that, in 1924, Mr. Hoover refused to issue any further licences and for two years the situation was stabilized. However, it must be remembered that, from the beginning, broadcasting in the United States was on a commercial basis, with programme material paid for by advertisers. Mr. Hoover's ban was therefore keeping other concerns out of a lucrative business, and in 1926 the Zenith Radio Corporation challenged the Secretary's authority to control radio and won the ensuing lawsuit. This left the field free for anyone to enter without regulations or restrictions—a chaotic state of affairs which was ended in 1927 by the passage through Congress of a law establishing the Federal Radio Commission as the licensing authority. The Commission, with the assistance of the Institute of Radio Engineers, soon after its formation issued rules and regulations for all radio services. In 1934, the Communications Act broadened the functions of the Commission and renamed it the Federal Communications Commission.

Canada.—The first station in Canada, owned by the Canadian Marconi Company, began broadcasting in December, 1919—almost a year before the opening of KDKA. The choice of the regulating authority for broadcasting appears to have been made in as haphazard a way as in the United States, since the Department of Naval Service undertook the duty until July, 1922, when it was transferred to the Department of Marine and Fisheries. This body was immediately faced with the serious problem of interference with reception in Canada from United States stations, which by 1923 occupied every frequency within the band, including those on which Canadian stations were trying to work. It was not until 1926–27, however, that international talks were held; but these reached no agreement, since the United States offered Canada no more than six clear and 12 shared frequencies, reserving the remaining 77 for her own use, and this was considered by Canada to be insufficient for the very wide coverage required. In spite of the lack of agreement, however, the newly established Federal Radio Commission did clear six Canadian channels, which somewhat eased the position.

By 1929 Canada had about 80 licensed stations and nearly 300 000 licensed listeners, since the British practice of issuing receiving licences had been adopted in 1922. Throughout this period continuous complaints regarding the nature and amount of advertising carried by some stations had been made to the Department of Marine by listeners, and in 1928 the Department refused to renew the licences of four stations which were owned or used by an organization alleged to be unpatriotic, pacifist and an advocate of religious intolerance. This action aroused such a public outcry that a Royal Commission under the chairmanship of Sir John Aird was appointed to examine the whole broadcasting situation. The report of this Commission, submitted in September, 1929, recommended the setting up of a public corporation to take charge of all chain broadcasting on a national basis, leaving the private stations to cater for the more local needs of listeners.

However, action on this report was delayed for various reasons, and it was not until 1932 that a Parliamentary Committee was appointed to consider what should be done. This Committee repudiated the proposal to set up a corporation, and suggested instead a three-man commission to regulate and control all broadcasting as well as to operate a national network. As a result of these recommendations the Canadian Radio Broadcasting Commission began its operations in January,

1933, and had organized a regular schedule of national broadcasting by May of the same year.

It soon became clear that the task which the C.R.B.C. had been set was beyond the powers of so small an organization, and that its financial resources from licences and advertising were completely inadequate. After a difficult and highly criticized period, another Parliamentary Committee, appointed in 1936, made recommendations which virtually reverted to those of the Aird Commission and resulted in the establishment of the Canadian Broadcasting Corporation on the 2nd November, 1936, with powers, duties and functions which apart from minor amendments made in 1944 and 1947 remain unchanged until now.

Although, so far as the operation of a broadcasting system is concerned, the C.B.C. bears many resemblances to the B.B.C., on which indeed it was in most respects modelled, the existence in Canada of private stations results in the C.B.C. being given regulatory power over both the technical functioning and the programme material of such stations. So far as technical matters are concerned, the C.B.C. theoretically acts solely in an advisory capacity to the Radio Division of the Department of Transport, which occupies much the same position as that of the Radio Division of the British Post Office or the Federal Communications Commission in the United States.

International Negotiations.—After the international discussions of 1926, further meetings were held in Washington in 1927 and in Ottawa in 1929, but it was only through the establishment by the Havana Convention (1937) of the North America Radio Broadcasting Association that any really workable solution of the problem was reached. However, since Mexico delayed ratification until 1940, it was not until March, 1941, that the agreement came into effect for a period of five years. At this time Canada was already at war, and with the United States joining in before the end of the year, conditions were by no means ideal for implementing all the complicated conditions. After the expiry of the agreement in 1946, a meeting in Washington, failing to find any comprehensive substitute, established a *modus vivendi* which extended special privileges to Cuba and was designed to last until January, 1949. New negotiations among the six members of the N.A.R.B.A. (Canada, Cuba, Dominican Republic, Haiti, Mexico and the United States) were opened in the middle of 1949, first in Montreal and later in Washington. Even in the absence of Mexico from a considerable portion of the negotiations, a treaty was finally produced, but at the time of writing only Cuba has ratified it. As an indication of the complexity of the problem facing the negotiators, it may be mentioned that the total number of radio stations listed in the treaty is 2992. In view of the many extremely diverse interests seeking satisfaction—commercial, Governmental and nationalistic—it would seem unlikely that the recently concluded treaty will be by any means the last word on the subject.

Frequency Allotment

The problem of fitting in nearly 3 000 stations into a waveband containing only 106 channels is obviously an extremely complex one, which has been solved with reasonable success only by strict adherence to a complicated set of rules and regulations worked out by N.A.R.B.A. in conjunction with the various controlling bodies.

The interpretation of these rules, as contained in an F.C.C. publication "Standards of Good Engineering Practice concerning Standard Broadcast Stations" occupies 42 printed pages, together with 30 sheets of curves, so that only a general summary can be attempted here.

The available channels are allotted in three different classes, so-called "clear" channels primarily for high-power stations, regional channels for medium-power stations and local channels for low-power stations. The stations themselves, however, are grouped into four different classes, two of which are subdivided further. The class to which a station will be allotted depends on the service area which it is intended to cover, which in turn is decided on commercial and geographical, rather than technical, grounds. The various classes of station are then assigned to channels in accordance with rules mainly designed to give protection against interference from other stations on the same or adjacent channels. Such protection is afforded over an area bounded by a definite field-strength contour, the field strength chosen depending on the class of station under consideration.

Class I stations have power outputs between 10 and 50 kW and are designed to cover large areas both by ground-wave and sky-wave propagation. They are thus the most carefully protected (and least numerous) group. The class is subdivided, Class I-A comprising those stations which are given sole night-time occupancy of their channels. Class II stations may be permitted to work on the same channel during daylight only, and even so must protect the Class I-A station so far as the 100 μV/m ground-wave contour. Class I-A stations, which must radiate 50 kW, are protected from adjacent-channel stations as far as the 500 μV/m ground-wave contour both by day and by night. Class I-B stations do not enjoy the sole occupancy of their channels, which are shared by other Class I-B or Class II stations, without time limitations. Protection is afforded to the 500 μV/m 50% sky-wave contour* by night, and as far as the 100 μV/m ground-wave contour by day, with the same adjacent-channel protection as Class I-A stations.

Class II comprises those stations with outputs ranging from 250 watts to 50 kW which occupy subordinate positions on the "clear" channels, being required to protect the Class I stations as already described. They, in turn, have to be protected as far as the 2 500 μV/m ground-wave contour.

Class III comprises the regional stations and is also subdivided. Class III-A stations (outputs from 1 to 5 kW) are protected as far as the 2 500 μV/m ground-

* The 500 μV/m 50% sky-wave contour runs through the points at which the sky-wave field strength exceeds 500 μV/m for half the time on the average.

wave contour by night and as far as the 500 μV/m contour by day. In Class III-B the powers range from 500 watts to 1 kW by night and 5 kW by day, while the night-time protection extends only as far as the 4000 μV/m contour.

Easily the most numerous, Class IV stations work on the local channels with powers between 100 and 250 watts. The only protection afforded is by day as far as the 500 μV/m ground-wave contour. These little stations, with sometimes a hundred or more throughout the continent sharing the same channel, perform a function in relation to the surrounding population which may best be compared with that of the local newspaper, and they have no counterpart whatever in the British system.

From this very condensed survey of the principal assignment rules it will be seen that the present situation is practicable mainly because it has developed gradually. As each new station has been licensed it has had to fit itself into the existing allocation, protecting all other stations on the same or adjacent channels to at least the degree laid down in the regulations, while existing stations are under no obligation to make changes to protect the newcomer. This has meant, in many recent instances, that even comparatively low-power stations have had to erect complicated directional aerials in order to cut down their radiation in certain specified directions. Thus, it is obvious that any wholesale attempt to re-arrange the present frequency allocation (of the type which occurs at each successive European conference) would result in changes of such complexity as to render it virtually impossible to effect. This means that, apart from any such unforeseen occurrence as the setting up in the United States under Government control of a regional network such as exists in Britain, no change in the present situation, other than the process of gradual development, is at all possible.

Transmitter Technique

The whole trend of the regulations regarding transmitters, aided by the normal tendency towards standardization, has resulted in the adoption of a number of standard power-output ratings for broadcast transmitters, namely 100, 250 and 500 watts, and 1, 5, 10, 25 and 50 kW. Of these, the most common values are 250 watts and 1 kW. Most manufacturers therefore concentrate on building and stocking transmitters of these two ratings, other sizes being made to order. Design is usually quite orthodox, although each manufacturer tends to have his own special features.

As already mentioned, directional arrays play a much more prominent part than they do in Britain, and for this reason phasing units and aerial coupling circuits are highly developed. Transmission lines range from the nitrogen-filled coaxial type to the open-wire type, and mast radiators are almost universal. These are normally fed at the base, although in some instances a shunt feed to a point part of the way up the mast has been used, with the base of the mast earthed.

There is a growing tendency to equip transmitters with various forms of remote control and telemetering or alarm circuits, so as to allow unattended operation. This is especially the case with lower-power stations where the salaries of transmitter operators can form an appreciable fraction of the total operating costs. In the more sparsely populated districts of Northern Canada, considerable use is being made of unattended transmitters of very low power, permanently bridged across the network lines. In this way, a programme service can be provided in small isolated communities, where it is especially valuable in the absence of other forms of entertainment and information.

The regulations in all countries call for the provision at the audio input to the transmitter of a limiting amplifier with a limiting range of not more than 6 dB, in order to reduce the likelihood of overmodulation. Where directional aerials are used, phase monitors are required for checking the operation of the system so as to ensure that the desired polar diagram is maintained. All stations must be equipped with a frequency monitor having an absolute accuracy of $\pm$ 10 c/s, while the transmitter itself is required to be accurate to within $\pm$ 20 c/s of its nominal frequency. The relatively small difference between these two accuracy figures would suggest that the monitor is intended principally as a check against fault conditions in the transmitter oscillator rather than slight variations from the assigned frequency.

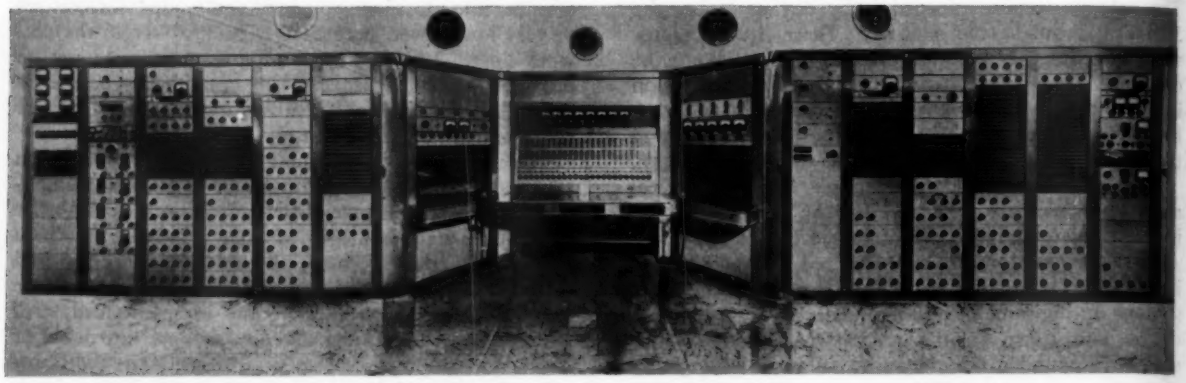
Studios

It is obvious from the nature of the American system, comprising as it does everything from the huge network operating many stations and affiliated with many more to the little independent community station serving a district with perhaps less than 25 000 inhabitants, that broadcasting studios will show a tremendous range of variation. On the one hand are the great centres like those in Radio City, New York, or the Don Lee System in Hollywood; on the other, often a single floor of a small building contains the control room, two studios, and office space sufficient for the needs of a small station. Modern practice may perhaps best be illustrated by means of two examples, first the Radio Canada Building in Montreal—one of the main centres of the C.B.C. networks—and secondly a typical station with from two to four studios.

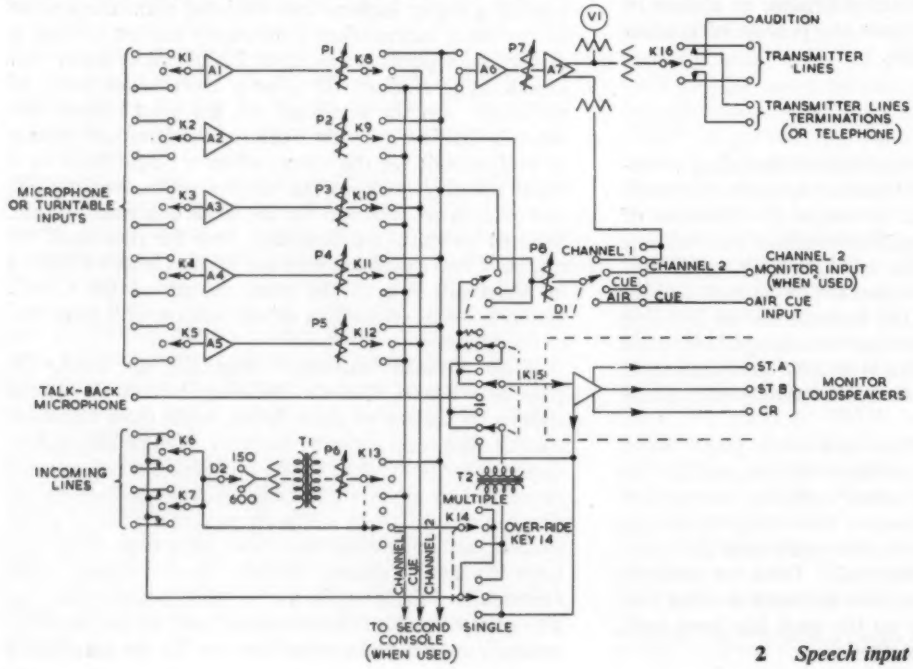
Radio Canada Building.—Originally an hotel, the 12-storey Radio Canada Building houses 26 sound studios on the lowest three floors, while three television studios occupy an annex to the rear. The sound studios, designed by the C.B.C.'s own architectural department, range in size from three large enough for symphonic programmes to those designed principally for a single speaker, although even these have been kept adequately large to avoid serious trouble from isolated room resonances. Each studio has its own control room, but two groups, each of three studios, may be worked from specially constructed control consoles for use particularly

in complex dramatic or musical presentations. The control rooms housing these special consoles are so arranged that the operator has a clear view into each of the studios in his group. Another rather unusual facility is the provision of small booths adjacent to the two main studios expressly for the purpose of inserting foreign-language announcements into musical programmes. This is required principally for the C.B.C.'s international service, but can also take care of the bilingual nature (French and English) of some of the C.B.C. home programmes.

With each studio or group of studios being a completely self-contained programme-producing unit, the function of the central or "master" control room is reduced to switching, distribution and monitoring. Even so, the master control equipment in the Radio Canada Building (illustrated in Fig. 1) is probably the largest on the North American continent, with a unique preset switching system having 24 inputs from studios, etc., and eight output circuits feeding networks. This system allows the master-control operator (there is normally only one) to preset the connections which are due to become effective at a later time, the actual switching being performed automatically as the studio operator closes his output key to start the programme. Associated with this master-control equipment is a recording switching system which gives an instantaneous choice of any one of 50 programmes to each operator in the nearby



1 *The master-control equipment in the Radio Canada Building*



2 *Speech input equipment for a small station*

recording room. A further switching system gives a similar choice to the occupants of 50 offices around the building.

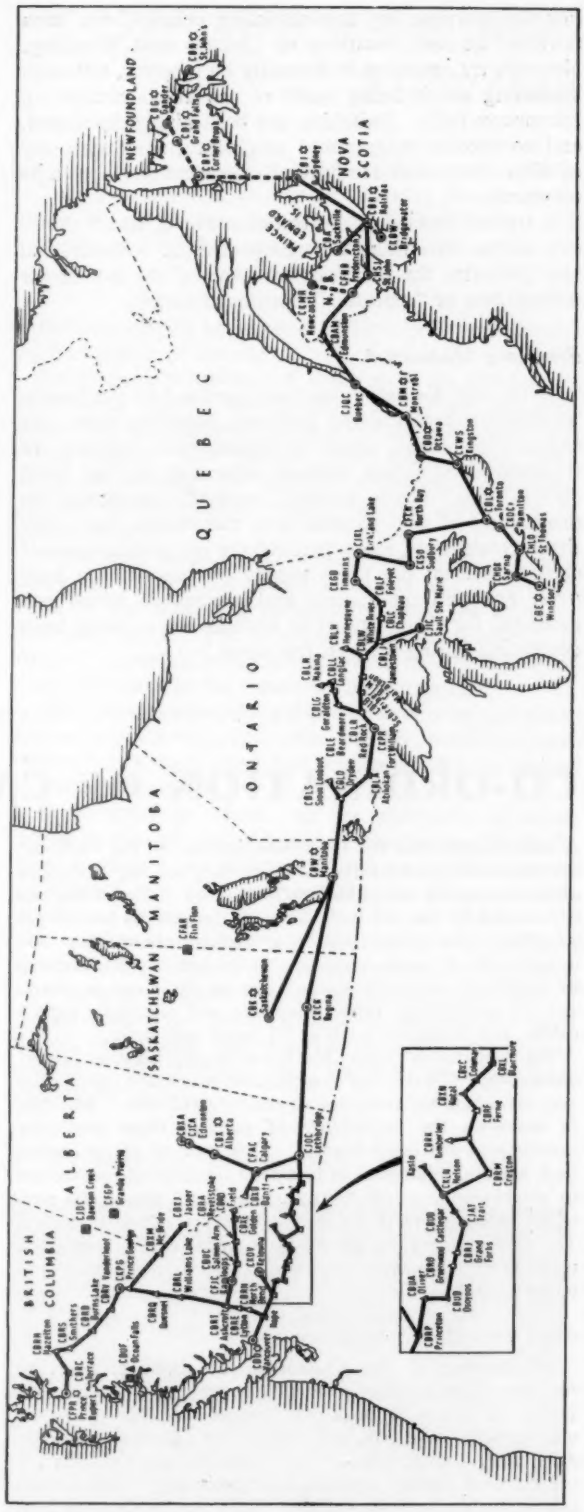
A Small Private Broadcasting Station.—A station of this type usually possesses from two to four studios, although with four studios one or two may be very small rooms large enough for only a single speaker or announcer. Either one or two control rooms are provided, equipped with control console equipment designed to allow the greatest possible flexibility of working. The schematic of a typical example is shown in Fig. 2, from which it will be seen that up to ten microphones or turntables may be connected, and five of these may be in use simultaneously. Four outside-broadcast lines are provided, only one of which can be used at a time. In the interests of economy, provision is made for feeding a cue programme back down these lines; or the studio operator can talk back to the operator at the outside-broadcast point, thus saving the expense of an additional control line.

In the small station a very great proportion of the programme material will be recorded, either on discs or tape; 16 in transcriptions, lateral or vertical cut and operating at 33⅓ r.p.m., were at one time the most important source of recorded material and are still widely used, both for disseminating commercial shows where lines are either not available or uneconomical, and, in the form of record libraries, for providing basic material from which programmes can be locally assembled. Recently, however, the introduction of magnetic recording and of the long-playing record has reduced the importance of the transcription disc.

A typical small-station control room will therefore have, besides the control console, a magnetic-tape recorder reproducer and from two to four 16 in turntables designed for 2- or 3-speed operation and each equipped with a suitable pick-up arm and pick-ups to cope with the present variety of records and transcriptions.

Network Broadcasting

In both the United States and Canada, extensive networks are in continuous operation for the simultaneous broadcasting of common programmes from a number of associated stations. Four of these in the United States and two in Canada extend from coast to coast, while numerous others cover smaller areas. Owing to the differences in standard time between the various zones, it is often necessary to delay programmes originating in the east to ensure the best listening periods in the west.



3 *The trans-Canada network of the C.B.C.*

Stations
- Basic.
- Supplementary.
- Pick-up and rebroadcast from C.B.C. stations.
- C.B.C. owned and operated stations.
- C.B.C. repeater stations.
- C.B.C. repeater stations in process of construction.

Wire Links
- Basic.
- Supplementary.

For this purpose big tape-recording centres have been provided at such locations as Chicago and Winnipeg. Network transmission is normally by landline, although increasing use is being made of the audio circuits on microwave links. Switching has been highly developed, and composite programmes originating simultaneously in New York and Hollywood, for example, are quite common.

A typical network is illustrated in Fig. 3, which shows one of the two English-language C.B.C. systems and also indicates the locations of some of the low-power transmitters or "repeaters" mentioned earlier.

Frequency Modulation

So far, our discussion has been confined to amplitude-modulation broadcasting stations; however, there has existed for many years a considerable number of frequency-modulation stations operating in the band 88–108 Mc/s. These stations normally duplicate the programme of an associated a.m. transmitter, but sometimes concentrate more particularly on programmes of classical music; but for a variety of reasons they have never achieved the success and acceptance which was predicted for them, and their number has actually been decreasing during the past few years.

One particularly interesting application of frequency-modulation is in the Rural Radio Network which covers a large part of the State of New York. This is based on WQXR, a 50 kW a.m. station owned by the *New York Times*, and WQXR-FM, its f.m. counterpart. From this latter source the station's programme, consisting mainly of hourly news bulletins and live and recorded classical music, is picked up by a number of other f.m. stations and retransmitted, the process being repeated from point to point, thus eliminating the need for landlines, while maintaining excellent quality throughout the network.

Conclusion

In many ways the contrast between North American and European broadcasting is a reflection of differences in national character and interests. Within the North American continent, the differences between the practices of the United States and Canada are themselves significant, those of Canada having something in common with those of both the United States and Britain. Yet from an engineering point of view each system achieves the desired fundamental result—the dissemination of one or more programmes as widely, as cheaply and as faithfully as possible.

CO-ORDINATION OF CATHODIC PROTECTION

A Joint Committee for the Co-ordination of the Cathodic Protection of Buried Structures has been set up. Evidence of the increasing use of the method in the United Kingdom is provided by the fact that, although the records are not yet complete, information has been received about some 300 installations, either in operation or projected. Installations by impressed current or reactive anodes are in use on water, gas, oil and sewage pipes, telephone and electricity supply cables, and structures such as oil tanks and jetties.

The need for co-ordination arises largely because current circulating in the soil due to a cathodic-protection installation may accelerate the corrosion of nearby structures. Methods of assessing the probability of damage from particular installations are being studied. One method of preventing such harmful interaction is to extend the cathodic protection to neighbouring structures by connecting them to the protected structure, with suitable safeguards where necessary. The Committee have, therefore, to consider the conditions under which such interconnection of buried structures should be permissible.

Constitution of the Joint Committee

Membership of the Committee has been confined to representatives of organizations or industries responsible for buried structures. The Committee is meeting under the chairmanship of Mr. W. T. J. Atkins of the Central Electricity Authority, and at present the following organizations are represented: British Transport Commission; Central Electricity Authority; Area Boards; Gas Council; General Post Office; United Kingdom Pipelines; and Water Research Association.

The Technical Panel

Since it will ultimately be necessary to publish the findings of the Committee in a Code of Practice, a Technical Panel has been set up having the following terms of reference:

> To study cathodic protection with a view to the eventual drafting of a Code of Practice, with special reference to the possibility of cathodically protected systems endangering adjacent buried structures, and to joint protection schemes.

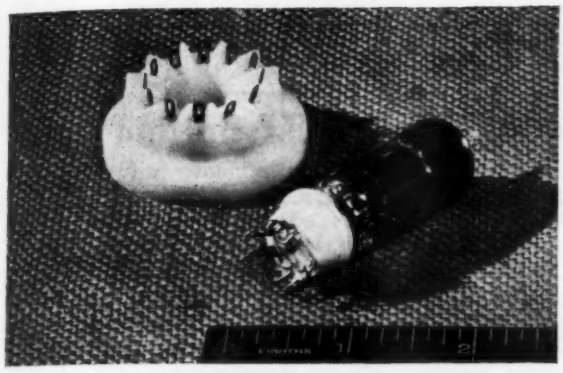
The membership of the Panel consists of one representative of each of the organizations listed above, together with Dr. F. Wormwell, of the Department of Scientific and Industrial Research, who is Chairman of the Panel, Dr. T. P. Hoar and Mr. K. A. Spencer.

Arrangements have been made to ensure liaison with the British Cast Iron Research Association, the British Electrical and Allied Industries Research Association, the British Iron and Steel Research Association and the British Non-Ferrous Metals Research Association, and the Committee intend, in due course, to seek the collaboration of the Council for Codes of Practice so that the proposed Code may be published as one of the series of British Standard Codes of Practice for which that Council is responsible.

Communications regarding the work of the Committee should be addressed to Mr. J. H. Gosden, Secretary to the Joint Committee on Cathodic Protection, Central Electricity Authority, Bankside House, Sumner Street, London, S.E.1.

The Radio Section discuss PLASTICS

On the 22nd November, 1954, Mr. Maldwyn Jones, B.Sc., delivered an informal lecture on "Plastics for the Radio Engineer" at a meeting of the Radio Section. His remarks, and the discussion, are summarized on this page.



1 *Valve bases in polytetrafluorethylene*

MR. MALDWYN JONES began by commenting that the rapid growth of the plastics industry is of particular importance to the engineer, because it provides him with an increasing variety of raw materials with attractive mechanical and electrical properties. Generally speaking, plastics are not structural materials, although their rigidity and strength can be improved by laminating with paper and textiles, and especially with glass cloth. On the other hand, nearly all have good electrical-insulation characteristics; some, like polythene and polystyrene, are outstanding, even at high frequencies.

Materials available vary from the relatively hard and rigid phenolic products to the tough temperature-resisting nylons and the softer and more flexible p.v.c. and polythene. Some of these plastics can operate at temperatures as low as −80°C, while more recently the introduction of polytetrafluorethylene has provided the engineer with an outstanding dielectric which can withstand temperatures up to 250°C. The electrical industry is already the largest user of the major products, p.v.c. and polythene, and is showing a growing interest in nylon and polytetrafluorethylene.

Mr. Maldwyn Jones then reviewed the properties of the principal plastics and their main applications, with special reference to developments such as the new transatlantic telephone cable, high-frequency television cables and radio and television components. He compared their properties with those of traditional materials such as wood, ceramics and metal, and referred to the effect of this range of new plastic materials upon design.

By means of slides and specimens, Mr. Maldwyn Jones showed data and examples of plastic products, such as radio components (Fig. 1) and cabinets, flexible micro-groove gramophone records, motor-car gears, battery separators and a section of the London–Birmingham television cable which has polythene insulation (Fig. 2).

In the discussion which followed his remarks, several speakers referred to the variable properties of plastics, and it was acknowledged that the electrical and mechanical behaviour of most of the materials are affected by temperature and moisture. Moreover, inherent dimensional instability can be aggravated by internal strains caused by bad design of moulds.

Despite the misgivings of some speakers, the potting in resin of circuits incorporating transistors had been done, but it is difficult because the resin is exothermic when setting. One speaker noted that ceramic radio components made by injection moulding of thermo-setting powder could readily achieve tolerances of 5 mils per inch.

Pleas were made for a simplification of the chemical terms for plastics, for standard colours and for reliable data on the materials, particularly when the sizes are unusually large. The inherently low fire resistance of organic materials is being improved, but the limitation from this must in the meantime be recognized.

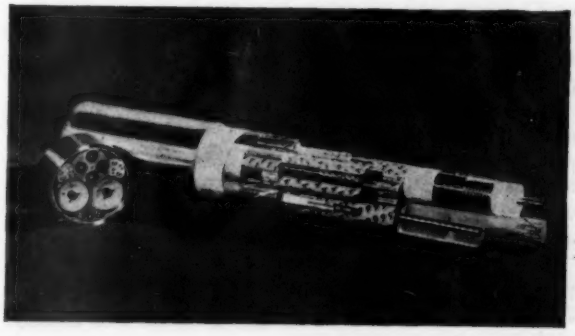
The reduced electrical surface resistivity of polythene when dirty was remarked upon, and Mr. Maldwyn Jones subsequently mentioned that surfaces could be treated to reduce this effect.

Some speakers referred to the possibility of using Terylene film instead of paper in capacitors, but at the present stage of manufacturing technique, although the stability of such films is acceptable, pin holes cannot be eliminated entirely.

A speaker was advised that efforts were being made to reduce the high price of polytetrafluorethylene. Remarks were also made about the scarcity of long nylon rods.

The value of iso-cyanide foam as an adhesive was mentioned, and tribute was paid to the similar proprietary substance which would stick metal to porcelain with exceptional tenacity.

2 *Section of the London–Birmingham television cable*



Journal I.E.E., June 1955

AREA BOARDS IN A LEAGUE?

A Controversial Method of Comparing Power-Distribution Costs

Is there any useful way in which one can compare the distribution costs of the Area Boards, with all their differences in load, type and number of consumers, size of Area, etc.? At a lively meeting of The Institution on the 3rd February, 1955, Mr. D. J. Bolton, M.Sc.(Eng.), Member, set out to show that there is. He was presenting his paper entitled "A Criterion of Distribution Cost," in which he expounds a clever, though controversial, method of assessing the relative "economic efficiencies" of the Area Boards—a method which seems, especially, to have increasing use for the future, as further annual accounts of the Area Boards become available. Most of the speakers at the meeting did not, indeed, take to Mr. Bolton's method and its results. But, as we shall see below, these results have a geographical bias, which, whatever the cause (and there was more than one suggested at the meeting) is set against London and the Southern Counties. Would it be incautious—despite the objectivity of the London discussion—to suggest that the paper might have a smoother passage in Caledonian waters? For Mr. Bolton has in his paper added a few well-tempered notes to the two Scottish Boards' swansong, while in contrast the London Board appears to be somewhat out of tune. However, we must away from fancy and on to fact—at least fact as nearly as we can have it in the cost analysis of power distribution. What is in the paper and what points were made in the London discussion of it?

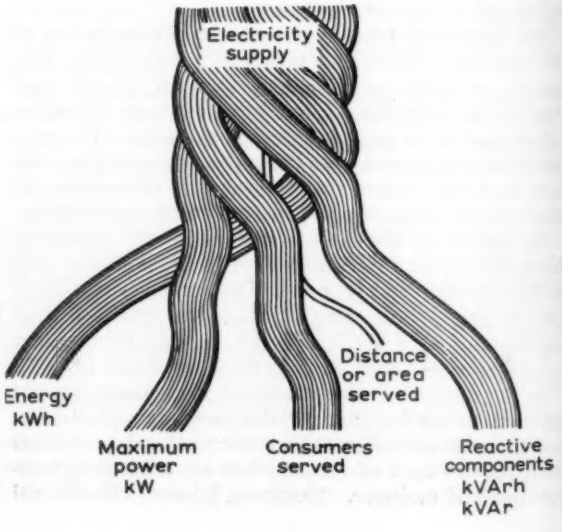
1. The Meaning of "Economic Efficiency"

BY "essential economic efficiency" (in this article the word "essential" is dropped) the paper implies the ability of an Area Board to minimize the cost of distributing electricity to its customers, who are thought of as a fixed set in the year under consideration. Each Board is faced with a consumption pattern due to its set of customers, and this pattern varies from Area to Area, in respect of type and number of consumers, size of Area, maximum demand, total energy supplied, etc.

All of these variables are under the control of the consumers, except for the area served, and in this respect the electricity supply industry differs from many manufacturing industries. Electricity supply may then be pictured as a rope (Fig. 1) made up of several distinct strands whose proportions depend on what each consumer demands. Each strand represents a physical, measurable quantity, which has a proportionally-related cost.* Economic efficiency does not in the paper comprise commercial achievement in such matters as winning more customers, persuading consumers to increase their purchases of energy, improving load factor, or increasing the sales of electrical appliances. Nor does economic efficiency have more than a secondary effect on a Board's revenue account; the governing factor in this, apart from the cost of the bulk supply to the Board, is the tariff charged. Any effect which a change in tariff has on the amount of power and energy supplied in a year is a "commercial" effect, and outside the compass of the paper. Mr. Bolton looks at the average pattern of consumption—no matter what historical, geographical, or commercial causes are responsible for it—which confronts each Board in a particular year, and assesses the relative economic efficiencies of the Boards in meeting their own consumption patterns, while compensation for the factors in the patterns that are outside a Board's control is made by the method of assessment.

* One speaker at the London meeting vigorously objected to the electricity supply industry being compared to rope!

1 *The strands of electricity supply*



2. *Measurement of Economic Efficiency*

The economic efficiency of an Area Board can be judged quantitatively only on a basis of the total cost per kilowatt-hour of energy supplied. But, as indicated above, so many of the costs making up this total are not dependent on a Board's management of its affairs and, moreover, cannot be treated as directly energy-related, that a simple calculation of the total gives a quite false indication of the Board's economic performance in a particular year. It is apparent that the cost of supplying 1 kWh will be less if each consumer takes 1 000 kWh than if he takes only 100 kWh, and less if he operates at a high, rather than a low, load factor. Mr. Bolton's method overcomes this difficulty by a system of cost relating, which compensates for these varying factors, and which is, in outline, as follows.

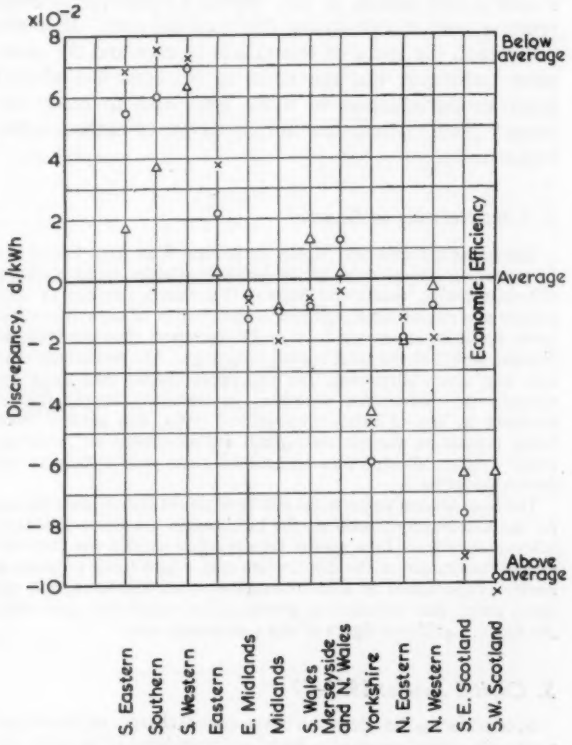
First, the total cost per kilowatt-hour of energy supplied to the whole of Great Britain in a financial year by all the Area Boards is split functionally into three components, related to the three major service variables, namely maximum demand (kilowatts), energy (kilowatt-hours), and number of consumers connected on the last day of the financial year; each component is expressed in pence per kilowatt-hour. The total cost per kilowatt-hour is thus thought of as made up of three components, one directly energy-related, and two others weighted so as to allow for the other cost, or service, variables. This procedure provides coefficients of proportion for the various types of cost (e.g. charges on assets, "common costs" such as overheads) in relation to the three components, averaged over the whole nation. Thus one coefficient gives the energy-related component of the charges on assets, another the demand-related component of the common costs.

Secondly, the coefficients are applied to the figures of assets, common costs, etc., for each Board separately, allowances being made for the individual sizes of the Areas, and a built-up or *notional* cost in pence per kilowatt-hour distributed is derived for each Board, by summation of the three components.

The discrepancy, or difference, between the notional cost and the actual cost (the latter is derived from the revenue received from the sale of electricity in a year minus the surplus associated with this sale) is used as a yardstick of a Board's economic efficiency. The discrepancy does, in effect, show by how much a Board is exceeding the standard distribution cost for its own consumption pattern worked out on the average of all the Boards' distribution costs, and it is implicitly assumed in the paper that this discrepancy is, at least partly, under the control of the members of a Board. When the actual cost is higher than the notional cost the discrepancy is taken as positive, and the smaller algebraically the discrepancy is the more efficient a Board is, relative to the other Boards. The sum of the products of each Board's discrepancy and its total sales of energy in a year is zero, a fact inherent in the procedure of calculation. The actual cost is made up of the bulk supply cost and the distribution cost; the former is accurately known, and it is only in relation to the latter that the discrepancy can arise.

3. *Individual Boards' Performances*

The calculated discrepancies for the financial years 1951–52, 1952–53, and 1953–54, are shown in Fig. 2,



2 *The relative economic efficiencies of the Area Boards*

A positive discrepancy shows that a Board is less efficient, and a negative discrepancy that it is more efficient, than the average. The Boards (with the exception of London) are plotted in the order in which they are officially scheduled.

× × × 1951–52. ○ ○ ○ 1952–53. △ △ △ 1953–54.

being plotted in the order in which the Boards are scheduled in the Electricity Act, 1947. The London Board is omitted since, as explained later, its assets are treated as a special case in a somewhat arbitrary manner.

It will be seen that, on the basis of Mr. Bolton's criterion, the two Scottish and the Yorkshire Boards had the highest relative economic efficiencies in all three years, and the Boards in the South of England the lowest. In general, the spread of the discrepancies among the Boards has been decreasing; in other words, there appears to be less variation in economic efficiencies than there was two years ago.

It will be noted that there is a striking geographical trend in the figures, distribution costs tending to be higher in the north than the south, a fact which has been

known qualitatively for a long time. The results given in Fig. 2 are, of course, not absolute; Mr. Bolton's method aims at enabling comparison of the Boards in any one year, and of an individual Board's performance from year to year.

Some remarks on the validity and limitations of the criterion are made at the end of this article, but first there follow a few details of Mr. Bolton's technique of cost-relating, and of calculating the notional cost. It is not possible in the space of this article to expound the complete technique, but the notes in Sections 4–8 should form an introduction to those who wish to study the paper* itself, where the author gives, of course, a full explanation.

4. Cost-Relating in General

The paper assumes that all the outgoings of an Area Board can be related to one or more of the service variables, namely energy (kilowatt-hours), maximum demand (kilowatts), number of consumers and size of Area, and that if the number of each of the first three variables appearing in a year's operation were doubled, so likewise would be the total annual outgoings. The second assumption may seem surprising, but the paper claims that there are virtually no "economies of scale" in electricity supply to-day. Payment in lieu of rates, management costs, and general overheads (excluding charges on capital) are all treated as "common costs" and are divided into component costs proportional to the service variables.

The cost-relating neglects the effects of power factor, since figures for the maximum demand on the bulk supply are not available in kilovolt-amperes. Low power factors affect chiefly the demand-related component of the distribution cost, which tends to be more nearly proportional to kilovolt-amperes than kilowatts, but the paper states that variation in power factor would only just affect the fourth significant figure of this component cost.

5. Capital Assets: 1951–52

In considering the allocation of the annual charges on the capital assets, the capital assets of a Board are considered to be related to maximum demand (kilowatts), number of consumers and size of Area, and to be independent of the energy supplied; the paper gives a national formula for this relation, which, when applied to each Board in turn, gives figures of assets whose total is equal to the national assets. To derive this formula, the capital assets of each Board are first plotted against the net maximum demand at the bulk supply points. The resulting graph is nearly a straight line, except that the point representing the London Board, which has very large assets on account of the high site values, lies well off it; the London Board is, in regard to capital assets, treated as a special case. Allowance is then made for the consumer-related assets: different values of the investment per consumer are assumed, to ascertain which value gives the best approximation to a straight line for the graph of demand-related assets (i.e. total less consumer-related assets) plotted against maximum demand. This process suggests a figure of around £15 per consumer in 1951–52 for the consumer-related assets, and this figure is adopted in the paper for all the Boards except London, for which £18 (20% increase) is used.

The formula allows for the effect of the size of an Area by weighting the demand-related component, so that it increases as the fourth root of the area per megawatt of maximum demand. The main justification for this rather arbitrary figure and for not weighting the consumer-related component also is that such weighting appears to make the revised graph of demand-related assets and maximum demand nearer a straight line than any other weighting. For London, the demand-related component is not weighted, since an increase in its area for a constant demand would tend, if anything, to decrease the demand-related assets of the London Board, because, for example, the site values of substations are lower on the outskirts of London than in its centre.

The formula deduced by Mr. Bolton is:

$$A = k_1 D + k_2 C$$

where A = first cost of fixed assets, £;
D = maximum demand at bulk-supply points, kW; and
C = number of consumers.

The values of the coefficients k_1 and k_2 are:

$k_1 = 43{\cdot}24$ for London:

$$23{\cdot}60 \left(\frac{\text{area in sq. miles}}{\text{maximum demand in MW}}\right)^{\frac{1}{4}} \text{ for other Boards.}$$

$k_2 = 18$ for London; 15 for other Boards.

This formula, applied to each Board in turn, with the values of C and D for that Board, gives individual (notional) values of A, which are not the actual values of the assets of the separate Boards but which on summation give the national total for A, namely £679·607 × 10⁶. The percentage of A to give the charge on assets for use in building up the notional cost of electricity for a given Board is considered in Section 7.

6. Capital Assets: Later Years

The same value of k_2 is used in calculations for the year 1952–53, with k_1 adjusted to give the correct total national assets from the formula when the 1952–53 figures of number of consumers and maximum demand in kilowatts are inserted in it. For 1953–54 Mr. Bolton has decided to change k_1 as well as k_2 to take into account the delayed effect of the higher post-war cost of new and replacement assets. Both the assets per consumer and the assets per kilowatt of maximum demand are in fact rising each year, and although the trend in the former tends to be constant, the individual yearly values of the latter are upset by exceptionally cold spells (such as occurred in February, 1954), which produce an abnormally high maximum demand. It is only the long-term trend in the assets quotients that is significant for the argument of the paper, and this is assessed as a 6⅔% increase in k_2 for the two years 1952–54, with a consequent increase of about 6¾% in k_1 to bring the total national assets correct according to the formula. These figures are used in the 1953–54 calculations.

7. Annual Expenses

Apart from the cost of bulk supply of energy and power, the annual expenses of each Board consist of expenses arising direct from electricity distribution and of expenses such as provision of hired apparatus, and public-lighting maintenance. The latter are assumed to be exactly equal to the "non-electrical" income (rentals of apparatus, surplus on contracting and sales, etc.) and are subtracted from the total combined expenses of the Boards, since they do not concern the subject of the paper; the resulting expenses of distribution amounted in 1951–52 to £84·765 × 10⁶, this figure being equal to the income from the sale of electricity plus the deficit on the year less the cost of purchase of electricity.

By analysis of the combined Area Boards' accounts, the paper shows that, of the distribution expenses, £55·910 × 10⁶ should be regarded as charges on assets. Now the national total of fixed assets at the close of the financial year 1951–52 was £679·607 × 10⁶, and thus the national coefficient for charges on assets in that year is 8·227%. This coefficient is later used in the building-up of the notional costs for individual Area Boards.

Certain distribution expenses, such as billing and meter-reading, can be related directly to the number of consumers; these are shown separately in the Annual Reports and totalled £13·17 × 10⁶ for the combined Boards in 1951–52.

The remainder (£15·69 × 10⁶) of the total distribution expenses

* To be published in Part A of the *Proceedings*.

Cost-Relating the National Distribution Expenses

Data and Assumptions

Item		Source*	
			× 10³
1	Consumers, total	[Appendix 5]	13 504
2	Consumers, London	[Appendix 5]	1 641
3	Consumers, excluding London	(1) − (2)	11 863
			£ × 10⁶
4	Consumer-related assets, London	(2) × 18/1000	29·54
5	Consumer-related assets, excluding London	(3) × 15/1000	177·94
6	Consumer-related assets, total	(4) + (5)	207·48
7	Fixed assets, total	[A. 16]	679·61
8	Demand-related assets	(7) − (6)	472·13
			MW
9	Bulk-supply maximum demand	[Derived from Appendix 5]	12 816
			kWh × 10⁶
10	Bulk-supply net energy purchased	[Appendix 5]	54 826
11	Energy sold to consumers	[Appendix 5]	49 708
12	Energy lost in transmission and distribution	(10) − (11)	5 118
13	Loss ratio	(12)/(11) × 100	10·29%
			£ × 10⁶
14	Bulk-supply cost	[C. 1]	170·21
15	Bulk-supply demand cost	4·125 × (9)	52·86
16	Bulk-supply energy cost	(14) − (15)	117·35

Schedule of Costs

Item		Energy-related		Demand-related		Consumer-related		Total
		Source	Cost £ × 10⁶	Source	Cost £ × 10⁶	Source	Cost £ × 10⁶	£ × 10⁶
17	Bulk-supply cost	(16)	117·35	(15)	52·86			170·21
18	Assets-proportional cost			8·227% of (8)	38·24	8·227% of (6)	17·07	55·91
19	Directly consumer-related						13·17	13·17
20	Sub-total directly related		117·35		91·71		30·23	239·29
21	Proportions (approximately)	(20) 49%		38%		13%		
22	Common costs	0·49 × 15·69	= 7·69	0·38 × 15·69	= 5·96	0·13 × 15·69	= 2·04	15·69
23	Sub-total distribution	(22)	7·69	(18) + (22)	44·80	(20) + (22)	32·27	84·76
			d./kWh		d./kWh		d./kWh	d./kWh
24	Bulk-supply cost per kWh purchased	$\frac{(17)}{(10)} \times 240$	0·514		0·231			0·745
25	Distribution loss on bulk-supply cost	(13) × (24)	0·053		0·024			
26	Distribution expenditure per kWh sold	$\frac{(23)}{(11)} \times 240$	0·037		0·216		0·156	
27	Total distribution cost	(25) + (26)	0·090		0·240		0·156	0·486
28	Grand total	(24) + (27)	0·604		0·471		0·156	1·231

* References in square brackets are to the B.E.A. Fourth Annual Report (1951–52). Figures in round brackets refer to items in this Table.

is the "common costs" and consists of administration expenses, payment in lieu of rates, and general overheads. It is argued in the paper that the common costs can be indirectly related to all three service variables—energy, maximum demand and number of consumers—and in fact it is the only type of expense that possesses all three components. The proportions in which the common costs are divided are taken to be those in which the other relevant expenses (cost of energy and power, and consumer expenses) when treated as a single total are found to be divided. On this basis, the coefficients of proportion for the energy-related, demand-related and consumer-related components turn out to be 49%, 38% and 13% respectively.

All electrical losses on the distribution side of the bulk supply points cause an additional distribution cost per kilowatt and per kilowatt-hour, although there is no corresponding item of expenditure in the Board's revenue account, for such cost arises only because of a reduction in the amounts sold. This cost is calculated with respect to both the demand and energy-related components of the distribution cost by multiplying each of them by the energy loss ratio (energy-lost/energy-sold). Figures for the maximum-demand loss ratio are not available.

Apart from variations in the power factor of consumers' loads, there are variations in the type of consumer which, strictly, invalidate the allocation of consumer-related costs uniformly in proportion to the number of consumers. Thus commercial and industrial consumers are likely to have greater costs per head than domestic and agricultural consumers for several reasons, including their higher consumption, more expensive metering, and the fact that they are a small group compared with domestic consumers; however, those industrial consumers using only high-voltage mains somewhat offset this effect. Mr. Bolton discusses in his paper the practicability of using a system of weighting to compensate for the variation in type of consumer, but he concludes that, as any system would be mainly empirical and the effect would appear only in the fourth significant figure of the calculated costs, there is little loss of accuracy in treating all consumers as the same.

The table shows the results of the above operations on the national totals for the year 1951–52.

For each of the calculations for 1952–53 and 1953–54, the figures of annual expenses given in the Area Boards' accounts for the relevant year are, of course, used.

8. Notional Cost

The average cost of electrical energy throughout Great Britain for 1951–52 is seen from the end-result of the Table (item 28) to be 1·231d./kWh, but this figure can, of course, be reached direct by dividing the year's income from the sale of electricity (£253·643 × 10^6) plus the net deficit on the year (£1·333 × 10^6) by the total energy sold (49 708 × 10^6 kWh). What has been done in the Table is to develop the idea of building up the notional cost from the energy-, demand-, and consumer-related components, and to calculate certain coefficients which can be used in the analysis of individual Boards. These analyses and calculations of the Boards' notional costs are made in a way similar to that shown in the Table. For the nation as a whole, the notional cost is equal to the actual cost; for individual Boards there are discrepancies, as explained in Section 2. The figures that are important for the individual analyses are shown in bold type in the Table. For example, the national coefficient for the consumer-related component of the common costs (see Section 7) is (item 22, col. 3)/(item 1), i.e. 2·04/13·504 or 0·151 £/consumer, and this figure is used in calculating the consumer-related costs per kilowatt-hour of electrical energy sold to consumers by an individual Board.

9. The London Discussion

The paper makes a skilful and gallant attempt at establishing a criterion by which the relative economic efficiencies of the Area Boards can be compared, and there must be few thinking people in Great Britain, of whatever political shade, who would not consider that is most desirable, always provided that it can be done accurately. Mr. Bolton's method ineluctably rests on certain assumptions, e.g. that the size of an Area has no effect on the unit costs, that there are no "economies of scale," and that average figures for the whole nation are truly applicable to the special circumstances of all the individual Boards. The treatment of the London Board is very tentative, and some of the arguments used about it should, perhaps, apply to other Boards containing large centres of population.

These and other controversial points were the raw material of many of the able contributions to the spirited discussion of the paper on February 3rd. In passing, however, it might be noted that one or two speakers appeared not to have read the paper carefully and to be relying on figures and comments supplied by colleagues. Two speakers remarked how glad they were to see that the Boards they represented were placed near the "top of the table," but—alas for them—those Boards have large *positive* discrepancies. For, although promotion cometh neither from the top nor from the bottom of Mr. Bolton's table,* the Boards that have fared best are, paradoxically, to be found in the lowest places.

Hardly a speaker really commented on Mr. Bolton's view that his criterion was likely to be more trustworthy as a basis for comparison from one year to another than for comparison of the Boards in any one year. Furthermore, there were a few red herrings grilled for the author and dished up as remarks about the importance of the Boards' "commercial" activities, including the necessity of improving load factor. No one would deny this importance, but the author had stated—even if not too clearly, as he later remarked—that he was concerned with economic efficiency only in the sense outlined in Section 1 of this article.

10. Appraisal

In opening the discussion in the Institution Lecture Theatre, Mr. C. T. Melling said he thought Mr. Bolton's paper was a very good approach to the question of distribution cost, but he doubted that it gave an accurate answer; there was, however, as yet no answer from any other source, and he sincerely hoped that the author would pursue the matter further. He stressed the limitations from having only 13 sets of data, and from the impossibility of measuring consumer service statistically. Owing to the traditions of the undertakings, Boards in some parts of Great Britain had to give more consumer service than others, and this fact was more important than the geographical position of the Boards *per se*. This comment seemed to imply that, very broadly, consumer service is better in the south than the north. Mr. Melling, like Mr. D. P. Sayers and several other speakers, did not favour the author's method of allowing for the individual area of each Board. He pointed out that some Boards have large tracts of moorland, etc., which could never need an electricity supply, and yet

* Not reproduced in this article.

would be included in the weighting of the demand-related costs by the fourth root of the area covered. He agreed with Mr. Bolton that it was wise not to try to correct for high-voltage consumers as against low-voltage ones, particularly since many rural consumers were supplied direct from high-voltage mains via transformers.

Mr. Melling emphasized that weather introduced a very serious difficulty into Mr. Bolton's calculations. The basic year for these, namely 1951–52, had reasonably favourable weather, with relatively low maximum demands. In other years (as noted in Section 6) cold snaps increased the maximum demands more in Areas with a predominantly domestic load than in "industrial" Areas. There was no correction for weather in the author's criterion. Mr. Melling disagreed with the author that there are no economies of scale, and in this view he was supported by Mr. T. G. N. Haldane and later speakers. If Mr. Bolton were right, how was it that with the expansion of the industry the costs of distribution and administration in an Area Board were the same as or lower than at Vesting Date, despite big increases in wages and other expenses?

Some support for Mr. Bolton's method came from Mr. Haldane, who spoke next. He thought the paper was of great value, though, on reading it, many criticisms had leaped to his mind; one was that there seemed to be no authority for the tacit assumption that the component costs varied linearly with the quantities (such as number of consumers) with which they were linked. He had considered the various gaps and uncertainties in the author's analysis, and, in particular, whether a more detailed analysis would have largely removed the varying discrepancies of the Boards, and he had concluded that the author provided at least an approximate yardstick for comparing the distribution costs of the various Areas, and that the geographical effect in the results was indeed a real one. As the discrepancies were tending to diminish each year, he wondered if they were due to causes that existed at Vesting Date and were gradually making their weight less felt with the passage of time; it was probably true that the conditions which faced the Boards in the south on Vesting Date were more chaotic than those facing the northern Boards. He too hoped that the author, and others, would investigate the subject of the paper further.

Speaking as a member of a Consultative Council, Dr. F. T. Chapman supported Mr. Haldane in the belief that the discrepancies would show considerable changes in succeeding years, and he considered that the author's criterion would be more trustworthy in 5–10 years' time than at present.

Mr. R. F. Richardson stressed the fortuity of a Board's maximum demand in any year, and that the capital expenditure of a Board is mainly proportional to the *potential* demand on its system. He stated that if the calculations for the South-Eastern Board in 1951 were made on the assumption of a load factor of 42% instead of 48%, the Board's discrepancy became 4·1 instead of 6·9, and the author's "League table" changed considerably. Any efficiency formula which relied on these fortuitous year-to-year figures was extremely dangerous. He declared that the assumption that the load factor of a Board varied from year to year at the same rate as the national average was quite wrong. After his earlier remarks, it was no surprise to learn from Mr. Richardson that at present the author's criterion could not be relied on; however, he considered that, after improvement, it could be useful in the future for comparing an individual Board's performance from year to year.

Mr. G. T. T. Rheam believed that the industrial consumer needed separating from the domestic one in Mr. Bolton's analysis. Like other speakers he was dubious about the comparison of demand-related costs, because of the variation in load factor between the Boards. He thought there must be something wrong with the author's method, since there was no logical explanation of the different results for the north and south.

The paper possessed merit for Mr. P. Schiller, although he criticized it on several detailed points, and he stated that the author's discrepancies did not represent anything connected with the efficiency of the Boards. "I feel," he said, "that it is mainly an expression of the long way we still have to go in finding an appropriate method of analysing and comparing the cost of distribution." The geographical trend might be connected with the well-known fact that the proportion of industrial supplies rises from south to north. In common with Mr. R. Baldwin and other speakers, he thought that this fact ought to be allowed for in the author's criterion.

Mr. F. H. Dennis had no use for the criterion, or, indeed, for the attempt to find one, since he thought there would never be agreement on the correct formula to be used. "It is easier," he remarked, "to invent formulae than to get them accepted." From the discussion of Mr. Bolton's paper, this remark would appear to be entirely true in its context.

Mr. Bolton was not in the least dismayed by the weight of criticism levelled against his method, and in the few minutes remaining to him—the meeting was an unusually long one—he replied effectively and wittily to many of the points made in the discussion. In particular, he maintained his position over economies of scale, pointing out that South-East Scotland, one of the smallest Boards, had one of the lowest discrepancies. If size had the effect indicated by some speakers a small Board would tend to be badly placed in the table of discrepancies, for its notional cost would not include a large enough component for common costs. He would not take sides on the question of consumer service varying with the geographical position of the Boards, but he thought that such variation was unlikely to be enough to account for the calculated discrepancies. He ended cheerfully by saying:

"I should like to thank the two or three speakers who compared my list to a sort of glorified Football League table, because that has given me a marvellous idea for the future use of my index. To encourage economy, the Area Boards can run a pool . . . in future years as the

Boards wander up and down the list, there may be an entirely new meaning for the term Bolton Wanderers."

11. Conclusions

What then are we to make of Mr. Bolton's criterion? It seems unlikely to win acceptance in the supply industry in its present form, and we can hardly wonder at this. It was noteworthy that in the London discussion not one speaker mentioned the comparative efficiencies of the management of the Boards. While so many uncertainties remain in the method, it would be wrong to look to these as a possible reason for the varying results; after improvement and with results over a series of years, the method may perhaps give some indication of this powerful ingredient of economic efficiency.

Although all the Boards supply electricity, they are as different as, say, the secondary grammar schools that all supply embryo men, and for mainly the same reasons—historical and geographical. To assess the "economic efficiency" of grammar schools in terms of the cost to the local education authority per boy matriculating at a university or per General Certificate gained is comparable to the task attempted in the paper. There are so many special circumstances associated with each Area, such as number of individual undertakings absorbed on Vesting Date, terrain, type of consumer, etc., that those who are members of the Boards which are badly placed need hardly feel perturbed—at present. Nevertheless, it is, perhaps, significant that Mr. Bolton's method accounts for the wide variation in the selling price of electricity throughout the country on a purely functional basis, apart from small discrepancies of the order of 5%. The method should become useful, especially for indicating trends in the economic efficiency of an individual Board from year to year; it would thus seem to have increasing application as results of more years become available and as Vesting Date slips into the limbo of the past. The comparative results over a series of years will tend to be independent of shortcomings in the method, and experience in using it will probably suggest modifications, which could be applied retrospectively for purposes of comparison. One of the dangers is that exceptional performance by other Boards in a particular year may vitiate the comparison of a single Board's performance over the years.

It is to be hoped that Mr. Bolton will accept the advice of several of the speakers at the meeting and follow up his paper with further research and analysis. With additional cutting edges and some regrinding, his economic tool should become of real service in assessing the Area Boards' individual conduct of their major activity and will, perhaps, explain conclusively the mystery of the curious geographical bias in their present costs.

HOME EVENTS

LONDON

THE KELVIN LECTURE MEETING

There was a very large attendance at The Institution building on the 21st April, 1955, to hear the renowned American scientist, **Dr. W. Shockley,** deliver the Forty-Sixth Kelvin Lecture on *Transistor Electronics.* The proceedings in the lecture theatre were televised to several receivers in another room, where an overflow meeting was held. A summary of Dr. Shockley's career was given on page 200 of the March *Journal.*

Before the Kelvin Lecture began the President, who was in the chair, presented a Certificate of Honorary Membership to **Mr. J. R. Beard,** and the Faraday Medal for 1955 to **Sir John Cockcroft.** In making the presentations, Mr. Eccles gave accounts of the careers of these two distinguished men, some notes on whom appeared in the March *Journal* on pages 174 and 175.

Mr. Beard received his award first, and in his reply he said:

Mr. Beard receives the Certificate of Honorary Membership from the President

"I can conceive no more heart-warming experience than to be chosen by one's colleagues for election to Honorary Membership of one's professional Institution. However, I cannot but feel that any value in my professional and institutional activities to which the President has referred in such generous terms is far more due to receiving a good start on my career than to any merit of my own.

"All I have done professionally starts from the fortunate fact that on leaving college I went to the North-East Coast. There is no doubt that, as one looks back on the first decade of this century, an exceptionally large proportion of the development of electricity supply was being carried out there. It was dominated by two vital persons, each with considerable genius in their respective spheres—Sir Charles Parsons, who was engaged on perhaps the most important stage of his turbine developments, and Charles Merz with his able team, all in their middle thirties, laying down the pattern of electricity supply as we know it to-day.

"My Institution activities were also given an early and favourable start by my being picked out at an early age by H. W. Clothier—another of the great figures on Tyneside—as a prospective Chairman of the Local Centre. I have always been very proud of having graduated into the higher circles of our Institution through my training in one of those Centres which are such a great source of strength to us. It was this early Chairmanship which resulted in my being on the Council when The Institution received its Royal Charter and, therefore, having my name recorded therein. I had begun to imagine I must be one of the few left of that 1920 Council, but on checking this I am delighted to find that a quarter of them still survive.

"Naturally looking back over the years there are many other important Institution activities with which I have been associated, and perhaps I might be permitted to mention a few.

"The first is quite a minor one in connection with the Specialized Sections. I was asked to open the discussion on the first paper read before the Transmission Section—now, of course, the Supply Section. I mention this because it is an opportunity for me to stress the growth of the Specialized Sections and the increasing importance which the Council attach to them. I believe they have been the means of preventing that unfortunate splintering which has been such a regrettable feature elsewhere. In the electrical field we have been successful in keeping in one fold the whole of the many-sided electrical industry and I believe that is something of which we can be justly proud. As far as I am concerned it has meant that I have made many friends in branches other than my own and have been able to keep a nodding acquaintance with their technical developments. What applies to me no doubt applies to all our members and has been much encouraged by the Specialized Groups in the Centres.

"The second is that I was closely concerned in initiating the informal meetings of the Presidents and Secretaries of the three major Institutions. During my term of office my opposite numbers were Sir Leopold Savile and Sir William Stanier, and I know how valuable these meetings proved straightaway. Though still informal, I have reason to know that their value has increased with the years and is primarily responsible for the really excellent relations which now exist between the three Institutions.

"The third activity in which I had a considerable share was the setting up of the original Codes of Practice Committee under the aegis of the Ministry of Works, and its subsequent development into the Codes of Practice Council of the British Standards Institution. This is a matter on which all professional Institutions have worked together in a very marvellous way and, I think, have achieved an organization which will be of lasting benefit to the professional engineer and the architect.

Sir John Cockcroft speaks after the award of the Faraday Medal, which he is holding in his hand

"Lastly I should like to refer to the opportunities I have been fortunate to enjoy of meeting our oversea members in India, South Africa and Rhodesia. It was, indeed, at such a meeting in Salisbury that I received a telegram announcing my election as an Honorary Member.

"Any work I have done for The Institution has been a true labour of love and has yielded rich rewards in the friendships which it has initiated and the technical knowledge which it has imparted. Therefore may I, from the bottom of my heart, thank you, Mr. President, and the Members of Council for this very signal honour which you have been good enough to confer on me."

The President then made the presentation to Sir John Cockcroft, who responded as follows:

"I am very much honoured by the award of the Faraday Medal, which I shall always treasure. I am particularly happy that for me it will commemorate the work that I have been fortunate in being able to do in bringing together the fields of nuclear physics and electrical engineering. I was most fortunate in being put on the right track in life by working under two great pioneers, first Professor Miles Walker, an electrical engineer, and then Lord Rutherford. I am sure that if they had been alive to-day they would both have been thrilled and excited to see the way in which nuclear physics is now about to be applied in the field of electrical engineering."

Next the President called on Dr. Shockley, who had come over specially from the United States to give his

Dr. Shockley begins to demonstrate during the Kelvin Lecture the use of a silicon p-n *junction as a power rectifier*

lecture. From his opening sentences there was no doubt at all that this Kelvin Lecture would be a memorable one. In it Dr. Shockley engaged his audience with a sparkling account of the essential physics of semi-conductors. His delivery was compelling and he spoke almost entirely without notes; surely seldom before can a Kelvin Lecture have been so truly a lecture—rather than the reading of a distinguished scientific essay—and yet a lecture enlivened by practical demonstration, and one throughout which wit and wisdom jostled each other. Dr. Shockley has the rare gift of being able to talk intimately to a large audience, and the nonchalance with which, on an overcrowded blackboard, he developed formulae and made calculations from his head would have done credit to most college lecturers—albeit addressing classes of numerical size about equal to the square root of that of Dr. Shockley's audience. The intricate subject was expounded authoritatively and yet remarkably simply: even the electron-volt was defined for those who had trained as electrical engineers in the days of more tangible units of energy. Dr. Shockley animated his whole address with a sequence of technical witticisms, and of pithy asides that ranged from gamesmanship with the photographer to asking those sitting near him whether he had missed one of his own jokes.

During the lecture Dr. Shockley showed some 30 lantern slides, both monochrome and coloured, and towards its close he gave some revealing demonstrations of semi-conductor devices and apparatus employing transistors. At one point in this demonstration he threw handfuls of rejected transistors into the auditorium for anyone to catch who could. Certainly it was a unique evening in The Institution's annals. It was indeed a stimulating example of how a lecturer can make a difficult scientific topic come alive without over-simplifying the subject-matter. And the audience seemed to love it.

The full text of the lecture will be published in Part B of the *Proceedings* and it is hoped to publish an abstract of it in a future issue of the *Journal*.

Mr. H. Bishop proposed a vote of thanks to Dr. Shockley and this was seconded by Sir Gordon Radley.

EXTRA MEETING

Scent on the Wheels

Dr. H. I. Andrews presented his paper on *The Adhesion of Electric Locomotives* at an Extra Meeting on the 28th April, 1955, with Mr. S. E. Goodall, Vice-President, in the chair. The rather specialized subject did not attract a large attendance, but those present were treated to a most interesting discussion.

The paper, a digest of which appears on page 366, describes some investigations which have been carried out into the adhesion of the electric locomotives on the recently electrified Manchester–Sheffield–Wath line. In his brief introduction Dr. Andrews pointed out that, although the performance of the electrical equipment in a locomotive can be predicted accurately, the employment of this power for hauling trains depends entirely on the friction between the wheel and rail, where the area of contact is about the size of a sixpence. This was excellently demonstrated at the meeting, when carbon-paper impressions of the contact area were obtained by hammering together sections of the wheel tyre and rail.

The transient changes in axle load, which were measured during the track tests and were much larger than had been expected, were also demonstrated at the meeting by means of a film. It was amusing to hear that tests had been made with ester solutions, instead of sand, to try to improve adhesion, for such solutions are also used as the base of many perfumes and this had caused some embarrassment both to the investigators and to the locomotive.

The discussion was opened by Mr. C. C. Inglis, who emphasized the importance which the British Transport Commission placed on this subject by stating that it had set up an Adhesion Committee, which included representatives from the D.S.I.R. and industry. This committee would consider the whole subject from laboratory tests to field research and would welcome any suggestions.

While attention was drawn by Mr. A. G. Hopking to the fact that the locomotives were to-day performing duties more arduous than the designers allowed for in 1938, Mr. J. Koffman considered that the paper showed, in a very charming way, how not to design a locomotive, and he made some suggestions for improvement in line with continental practice. Mr. J. A. Broughall congratulated the author on the amount of detailed information included in the paper. He suggested that it might with advantage be made known also to the railway operating staff who are responsible for making up the train loads.

Five other speakers took part in the discussion, and among matters raised were the effects on adhesion of the pulsating torque of the a.c. commutator motor, of coupling rods and of parallel-connected motors. Some reasons were suggested for the variations in adhesion along the route, and concern was expressed at the low hauling capacity of the locomotives when adhesion is low. This underlined the importance of further development of reliable methods of increasing adhesion.

In his reply Dr. Andrews emphasized that the paper was an interim one only and that the results obtained so far appeared to be influenced by a "missing element," which is to be the subject of further investigation. He compared his present position to that of a man in a room who is trying to find out where the draught is coming from. While it has been suggested that the key-hole or the gap under the door may be the cause of this draught, it is also possible that further investigations may show that there is no glass in the windows. F. C. E. S.

MEASUREMENTS AND RADIO SECTIONS

A Calculated Contest

Interest in automatic computing would be lively if only the digital or the analogue type were being created, but with both emerging simultaneously, there is the added interest of a sporting contest, as first one and then the other makes some new advance. Dr. D. M. MacKay, at a joint meeting of the Measurements and the Radio Sections on April 5th, showed in his paper on *High-speed Electronic-Analogue Computing Techniques*, that in certain fields the analogue machine can challenge its rival—even in respect of speed, where it might be thought unchallengeable. A digest of the paper appears on page 367. Dr. MacKay describes circuit techniques by which distinct solutions can be presented from a general-purpose analogue computer at rates up to 25 000 solutions per second. By automatic variation of parameters, and "3-dimensional" cathode-ray-oscillograph displays, complete systems of solutions may be examined with convenience. Dr. MacKay even goes beyond "3-D" to "4-D," and at the meeting he showed lantern slides from which the sufficiently skilled are said to be able to view the relationship between four variables on a flat picture, but these exciting vistas were on the screen for too short a time to enable the uninitiated to appreciate much, except that they vaguely recalled the less intelligible kinds of modern art. One contributor to the discussion regretted that he had left his "4-D" spectacles at home.

In introducing the paper, Dr. MacKay said that the analogue machine as usually designed and used did not make adequate use of the information-handling ability of the thermionic valve. The machine he had constructed was the result of a systematic attempt to do so. He dealt briefly with the features of an analogue machine that set a limit to speed consistent with accuracy; especially the generation of functions—for which he used germanium-diode networks; multiplication—for which he used square-law amplifiers; programming, involving ingenious electronic resetting circuits; and above all, presentation of the results in assimilable form.

It does indeed seem that the chief limitation to usefulness of such high speeds lies in the presentation of results, and Dr. MacKay was careful to point out, both in introducing the paper and later, that analogue machines are not intended to compete with flight-simulators and the like, but to help to solve such problems as those of the quantum-physicist who wishes to explore the vast numbers of forms of solution of complicated equations for systematically varied combinations of many parameters.

The discussion was opened by Mr. D. J. Mynall, who thought that for function-generation the use of photo-electric curve-followers might be extended to high speeds, and need not be limited to functions of time. He also called attention to the unusually low gain of the amplifiers which in other situations would be unsatisfactory, and to the helpful circumstance that high accuracy is not required in a 3-dimensional display used for quantitative exploration. Mr. E. H. Cooke-Yarborough, too, was surprised by the amplifier design and wondered whether the drift that was so troublesome in low-speed working could be neglected just because the speed was high. It was explained later that this was only part of the reason, since for simplicity the diagrams shown did not include certain drift-correcting features that were used.

Lt.-Cmdr. F. R. J. Spearman asked also about drift-correction, and about the fields of use that the author of the paper thought his machine would suit. Mr. E. G. C. Burt contributed other suggestions for multiplication, and he was able to assure Mr. Mynall that diode circuits could be used, and were used, to produce non-linear functions of quantities other than time.

Mr. K. W. Thwaites, thirsty for further progress, suggested that the machine might be made automatically to vary its coefficient settings according to results, while Mr. C. A. A. Wass took the risk of being a wet blanket by pointing out that in some fields even real-time analogues turned out results faster than digital machines and certainly faster than our mental bandwidth could cope with. A similar slight scepticism was expressed by Professor C. Holt-Smith on the grounds that there was no point in generating a whole class of solutions in a millisecond, when it would be just as useful if the machine took a second to do so.

The questioners and the sceptics ought to have been well satisfied by the long and detailed reply of Dr. MacKay to the discussion, in which a great variety of technical points were cleared up.

The Chairman of this meeting was Mr. M. Whitehead, Chairman of the Measurements Section, and appropriately Mr. Oatley, Chairman of the Radio Section, proposed a vote of thanks. He said that Dr. MacKay not only had initiated a most interesting meeting, but had convinced him that the analogue was putting up a good fight and would continue to hold its place alongside the digital machines. A. T.

RADIO SECTION

Artificial Reverberation

Papers associated with the reproduction of sound are always of interest to engineers, and there was a good attendance on the 9th March, 1955, when a paper entitled *Artificial Reverberation*, by Dr. P. E. Axon, Mr. C. L. S. Gilford and Mr. D. E. L. Shorter, was read before the Radio Section. A digest of it appears on page 368.

The paper presents the subject from the viewpoint of broadcast studios, and Dr. Axon explained that separate "echo rooms" had been used since the earliest days, initially for dramatic effect and subsequently for supplementing the reverberation of the studio to produce a more natural effect. More recently, television studios, which are necessarily limited in acoustic design and are frequently very "dead," had given rise to a requirement for increasing reverberation artificially. Apparatus for variable correction had been developed and had been used by the B.B.C. for some time, making use of a magnetic recording device as the delay element, supplemented by an ultrasonic reverberation tank. A demonstration was given with musical recordings in order to show the flexibility of this apparatus.

Dr. G. F. Dutton opened the discussion by emphasizing the importance of an acoustically correct environment for recording or transmission, and compared echo rooms with acoustic- and magnetic-delay systems, but he felt that the paper tended to underestimate the importance of the higher frequencies and that the frequency range should be well up to 10 Mc/s. He gave his opinion of several recent programmes where reverberation had been used and finally pointed out that the method developed by the authors should be valuable for research on studio acoustics. Mr. Philip Bate spoke of the value of the apparatus to the television and radio producer, who is so often faced with an unsuitable studio, and inquired if there was any method of obtaining a mass opinion from audiences whether the degree of correction applied was generally acceptable. Dr. R. C. G. Williams gave some information on the application of artificial reverberation to popular recordings, where it was often used to excess for deliberate effect and suggested that some co-operation might be desirable when a popular recording artist was transmitted "live" in a television programme. Mr. W. H. Livy inquired about the background noise and high-frequency distortion introduced by the apparatus demonstrated. Mr. G. Conan supported this by asking to what extent the signal/noise ratio was worsened by the amplifiers, and queried whether the performance figures agreed with the practical result. He also raised some problems of mechanical tolerances and the extent to which they could be maintained in practice. After several speakers had expressed varying opinions about the desirable degree of reverberation, Mr. Smale suggested that it would be preferable for the conductor rather than the producer to have control over the acoustic correction introduced. He particularly associated the impression of noise with increasing reverberation and inquired whether the frequencies causing the noise effect could not be removed, with retention of the reverberation. Mr. R. D. Petrie made some heartfelt remarks on the deterioration of musical standards in the young caused by excessively reverberating crooners, and on a more serious note inquired about the mechanical reliability of the apparatus described. Mr. F. Williams, while complimenting the authors on an elegant piece of development which had important applications in the differing conditions of sound and television broadcasting, questioned whether the cost was justified compared with the possibilities of a generously proportioned basement echo room, even in the centre of London.

The authors in reply dealt with the various questions and suggestions on the construction and operation of the apparatus, and said that the increased noise is to some extent inevitable with reverberation since the sound goes on longer, while high-frequency distortion should certainly be small in ultimate effect. A great deal of work is going on in the United Kingdom and elsewhere to determine the preferred amount of reverberation.

The Chairman, Mr. Oatley, proposed a vote of thanks to the authors at the close of the meeting. R. C. G. W.

SUPPLY SECTION

Papers on circuit-breakers and their testing can usually be relied upon to attract a healthy attendance and a spirited discussion, and those on *Proving the Performance of Circuit-Breakers, with particular reference to those of Large Capacity*, by Mr. J. Christie, Mr. H. Leyburn and Mr. J. F. Bird, and *A New Testing Station for High-Power Circuit-Breakers*, by Mr. Christie, Mr. Leyburn and Mr. R. W. Fenn, which were presented and jointly discussed on the 23rd March, 1955, were no exception. A digest of the papers appears on page 371. The authors, in their introductions, clearly indicated the fields in which battle might be joined, and were probably not disappointed by the resulting clash of swords and, for the second paper, the music of rival trumpets.

The first paper set out detailed proposals for additions and changes to the standard proving tests for circuit-breakers. In opening the discussion, Mr. L. Gosland remarked on the number of proposals and on the impossibility of discussing all of them. That which most attracted his attention was the recommendation that single-phase tests (at full rating) on single poles of 3-phase breakers for effectively earthed systems should be made at a recovery voltage lower than the present accepted value of 1·5 times the phase voltage. On this, Monsieur Yves Baron, of the Société Français des Électriciens, whom the Chairman was happy to welcome, put the view generally supported by subsequent speakers from the user side. This was that some margin should be retained above what was strictly justifiable for the corresponding service conditions as a safeguard against other operating conditions giving rise to high recovery voltages and not

covered by specific tests. Mr. D. M. Cherry made the point that, although in service the high recovery voltage was not sustained, excess severity in the test could provide useful proof of the mechanical safety factors in oil circuit-breakers. Mr. C. H. Flurscheim suggested two testing standards, one with low recovery voltage for rather solid networks, as in Great Britain; the other with higher recovery voltages but lower rates of rise of restriking voltage for systems of weaker type. On the related question of the minimum recovery voltage for tests at reduced voltage on complete units, there was general support for the authors' proposals for an increase, but a strong feeling that they did not go far enough.

There was an interesting discussion on the rates of rise of restriking voltage, which the authors had suggested should be standardized. The values they put forward were higher than the French proposals, which M. Baron illustrated by a lantern slide, but lower than those desired by Mr. C. W. Mott, who showed how the values proposed in Great Britain had changed over the past five years. Mr. J. M. Hawkins thought an alternative standard to cover less severe operating conditions might be attractive.

Proposals for introduction into the schedule of tests at low current (5% of the rated short-circuit value) and tests on line dropping and on magnetizing-current interruption, were generally welcomed. To take account of conditions on the Grid, Mr. W. Casson proposed a single-phase test with current 30% greater than the 3-phase rated current but with recovery voltage appropriate to an earthed fault. Some concern was expressed at the large number (59) of tests which now seemed necessary to prove a breaker, but Mr. Mott counselled complainants not to despair, since he was aware of breakers for which the century had been passed.

The discussion on the second paper was more limited. Mr. G. F. Peirson inquired whether the authors would have used the U-connection of machine windings and over-excitation of their test alternators had they been designing new plant for independent use. Mr. J. S. Cliff, supported by Mr. Hawkins, argued with some vigour the superiority of super-excitation, indicating that to use it to best advantage the machines must be specially designed for operation with the stator iron well saturated. He thought the advantages obtained with the U-connection could be achieved equally well by more conventional means. The authors had designed rather large making-switches: their problems might have been eased if a lower voltage had been used for the transformer primaries. Mr. L. C. Walshe was disappointed with the progress of synthetic testing, and suggested the application of an auxiliary voltage between test circuit and tank to ensure simultaneous existence of maximum current and high voltage.

Wide as it was, the discussion, to which the authors replied as fully as time permitted, did not cover all the points raised in the paper. Some of the remarks raised a broad issue implicit in the topic but not explicitly posed; namely whether proving-test duties should include where possible a margin over service conditions to allow for variability, for the impossibility of precise calculation and for limitations of testing equipment in other directions. This question appears likely to remain with us, and doubtless for some time to come papers on circuit-breakers and their testing will continue to prove fertile soil for producing a vigorous and plentiful crop of speakers.

L. G.

Rural Flickers

A substantial contingent from the agricultural Midlands attended the meeting of the Supply Section at The Institution on the 27th April, 1955, to hear a reading of the paper on *Automatic Circuit Reclosers*, by Mr. G. F. Peirson and Mr. N. Care of the Midlands Electricity Board, and Mr. A. H. Pollard of the British Thomson-Houston Co. The paper described how a visit to the United States by Mr. R. Mallet of the Midlands Electricity Board aroused interest in the use of pole-mounted high-speed self-resetting automatic circuit-breakers for rural overhead lines. It also described subsequent successful operational experience in the rural areas of the Midlands on two types purchased from America. Mr. Peirson, who read the paper, stressed that during bad storms in early 1953 wind-borne salt deposits appeared on lines in the Leek District, resulting in insulator flashovers which caused one recloser to operate successfully 72 times before the trouble disappeared. No interruption was caused in the supply to consumers on this line. Co-operation between engineers of the Board and the B.T.-H. Co. has resulted in a British design of recloser which in some ways is more suitable for requirements in the United Kingdom. A digest of the paper appears on page 373.

The presentation of the paper was made all the more interesting by some excellent coloured lantern slides and by a home-produced film in sound and colour in which the Peirson cat demonstrated that 30 seconds of darkness provided by a slow-acting weight-operated reclosing circuit-breaker was just nice time for him to consume a newly opened tin of sardines. He nearly lost the laugh of the evening, however, because there was not a high-speed automatic circuit recloser in The Institution's sound-reproduction system. The film demonstrated how little the operation of the high-speed recloser affected the consumer's supply. It also showed how well it reduced the possible damage to insulators under flash-over conditions when compared with protection by fuses.

The discussion on the paper was opened by Mr. C. H. Flurscheim, who was clearly reluctant to bid farewell to the old weight-operated reclosing circuit-breaker which has been installed by the thousand and with which he is so familiar. He thought the manufacturers of the British high-speed recloser described in the paper had made a good job of the design, except that he would expect trouble from birds which might sit on the top of the tank and reach a live conductor. They would operate the recloser only if they were careful to peck the outgoing bushing.

Mr. G. O. McLean suggested that the fault statistics quoted in the paper did not agree with national figures made available to Chief Engineers of Area Boards for 1951 and 1952 and that the correct figures might not show the equipment in such a favourable light. He also criticized the decision to standardize on reclosers which, after going through their automatic operations, locked open in the face of a persistent fault. He thought that a recloser which locked closed would be better. The authors made the point that it was hoped later to introduce automatic line sectionalizers, and it would be technically impossible to use them in conjunction with reclosers which locked closed. They had therefore decided to standardize on reclosers which locked open.

Other speakers asked for information on current ratings, lightning statistics and on the use of reclosers on systems protected by arc-suppression coils, and for information on the maintenance which reclosers were likely to require—the authors recommend that they should be inspected once a year for this purpose, or after one hundred reclosures. Mr. P. E. Gaze said that the manufacturers would welcome any information which would guide them in making recommendations for regular maintenance.

Mr. R. Mallet shot the ground from under the feet of those who might be worried about the successful operation of reclosers, be it from birds, lightning, Petersen coils or interruptions for maintenance. He expected reclosers to be used on 11 kV lines erected to B.S. 1320, which does not require earthing of pole-top ironwork, and he therefore recommended that the tanks of automatic reclosers should not be earthed. Furthermore, he had been experimenting with a view to installing and removing reclosers without interrupting the supply on the 11 kV line—by "hot-line working" methods he had seen during his visit to America. Mr. Peirson was seen to nod his approval to this, from which we may expect some further developments from the Midlands at a future date.

Mr. Care and Mr. Pollard replied to the discussion briefly but effectively, and the Chairman, Mr. Peattie, thanked the authors for their paper, which upheld the tradition of the Supply Section through its One Hundred and Fiftieth Meeting. G. S. B.

A Day in Television Studios

The first of the two visits organized by the Supply Section Committee this year took place on April 30th, when, by courtesy of the British Broadcasting Corporation, 80 members of the Section visited the Lime Grove Television Studios and the White City Television Centre. After morning coffee had been served at Lime Grove and members had been welcomed by Mr. R. T. B. Wynn, the Chief Engineer, the party divided into two groups for visits to the Studios and the Television Centre.

The parties joined for lunch at the Myllet Arms, Perivale, where Mr. J. D. Peattie, the Chairman of the Section, took the opportunity of expressing the thanks of members for the excellent arrangements made for their visit. In the afternoon the two groups changed round, meeting together for tea at the Studios.

A most interesting day was concluded either by members witnessing a recording of the radio show *What Do You Know?* at the Playhouse Theatre, or the live telecast of *Variety Parade* from the Television Theatre.

UTILIZATION SECTION

At the meeting on the 14th April, 1955, Mr. W. Holttum presented his paper entitled *The Installation of Metal-Sheathed Cables on Spaced Supports*. In the course of his remarks the author pointed out that deformation of the sheaths of cables supported on posts, and possibly their fracture, would result through flexing by expansion and contraction with changes of temperature, and he then discussed the prevalence of such faults and the available means of preventing them. He reached the conclusion that the length between supports was the most important factor, and developed a formula for ascertaining what the minimum length should be in any particular installation.

In the very lively discussion which ensued, one speaker considered that the paper made an attempt to apply engineering methods to a haphazard principle and dealt with extreme cases only, while another expressed the view that a complicated formula is usually found to be incorrect. One contributor confessed that he had been rather frightened on reading the paper, for the practice of the concern with which he was associated was to run all outside cables on supports with nothing like the space recommended by the author; many miles of cable were installed in this way, but he had been assured by the maintenance engineers that there had not been one single instance of cracked lead sheaths with compound leakage. Reference was also made by other speakers to the possible effects of vibration on cables run alongside railway lines and to the probability that older cables provided a better opportunity of internal movement without sheath stressing.

The author, in a spirited reply to the discussion, expressed himself as being completely unrepentant in his views, notwithstanding that these had incurred more adverse than favourable criticism. R. H. R.

DEVON AND SOMERSET

SOUTH-WESTERN SUB-CENTRE

Since the last report in the *Journal*, the Sub-Centre have lost the services of Mr. R. C. Barton, a member of the Committee and the Local Editor. He has moved to Bristol; both he and his work will be greatly missed.

The meetings during February and March were of exceptional interest. Widely spaced at Torquay, Plymouth and Ilminster, all were well attended and all were well worth attending.

On February 17th the paper on *Submerged Telephone Repeaters for Shallow Waters*, by Mr. R. J. Halsey and Mr. F. C. Wright, was presented by Mr. Halsey in Torquay to an audience of 60, including many Post Office engineers. This paper has local interest, for some of these repeaters are installed on the Dartmouth–Guernsey cables. In addition, a description, by Mr. Halsey, of the deep-sea repeaters to be used on Atlantic cables, emphasized the anything but shallow manner in which Mr. Halsey dealt with his subject. Mr. Allwood's vote of thanks was warmly acclaimed.

The March ordinary meeting was held at Plymouth on the 24th of the month. The Chairman, Mr. H. C. O. Stanbury, had two pleasant tasks to perform. First he welcomed a new Corporate Member; secondly he announced that two students of the Sub-Centre, Mr. K. P. Hodge and Mr. J. P. Botterell from Plymouth and Devonport Technical College, had been awarded Institution prizes for their performances in the Higher National Certificate examination. The interest engendered by the paper *Aluminium-Sheathed Cables* by Mr. P. M. Hollingsworth and Mr. P. A. Raine was exemplified by Mr. W. E. Johnson of Paignton and Mr. E. W. A. Edmonds of Falmouth, who both brought samples of used cable for inspection. Mr. Johnson opened a lively and ductile discussion, made more topical by a reinforcement programme in Plymouth, which uses aluminium-sheathed cables. Despite Mr. Raine's protestations that he was a chemist, he seemed to find no difficulty in extruding informative answers. Mr. Hollingsworth was unable to attend the meeting. Mr. N. Axford moved the vote of thanks, and at tea £2 13s. 2d. was collected for the Benevolent Fund.

From cables to electronics at the District Meeting in Ilminster on March 30th, convened by Mr. C. H. Foulkes. Dr. Grey Walter, of the Burden Neurological Institute, Bristol, read a paper on *The Electrical Activity of the Brain*. Dr. Walter demonstrated this activity by apparatus which he brought with him, and by the aid of a member of the audience who acted as a "patient." The subject and the manner in which it was presented brought forth an amazing variety of questions, ranging from electronics to elephants. None of these, however, outweighed the lucidity of Dr. Walter's replies. G. B. H.

EDINBURGH AND GLASGOW

SCOTTISH CENTRE

The Annual General Meetings of the South-East and South-West Scotland Sub-Centres took place respectively on May 4th in Edinburgh and May 5th in Glasgow. At both meetings reference was made to the continued success of the federated constitution of the Scottish Centre, now in its third year, and at both meetings also the formal business was followed by an informal meeting.

In Edinburgh the custom was followed of reading short papers—one by a senior member and one by a member of the Students' Section. The senior member on this occasion was Mr. J. S. Pickles, who spoke on *Some Aspects of the South of Scotland Electricity Board*, of which he is Chairman. Mr. Pickles briefly outlined the legislation that had resulted in establishing the Board, the growth of load in the Area and the plans for new generating plant, including the Kincardine station; to keep things in perspective, he compared the total load of 2 000 MW that has been built up over the years in the whole of Scotland with the 2 200 MW demand of a single new atomic energy plant under construction in the United States. The second paper was given by Miss Sheila Weir, Chairman of the South-East Scotland Students' Section, and dealt with *Early Development of Radar*. This excellent and extremely well-delivered paper led to a very interesting discussion in which a number of members contributed their experiences as users or designers of such equipment.

In Glasgow the film on *The Chesters* was shown, preceded by a short outline of the activities and importance of The Institution's Benevolent Fund from Mr. R. H. Dean, the Fund's Local Treasurer. This was followed by the awe-inspiring film *Operation Hurricane* depicting the detailed preparations for setting off the atomic bomb at the Monte Bello Islands and culminating in the cataclysmic explosion; by a colour film showing the construction of the 275 kV Grid lines in which the breath-taking acrobatics of linemen 150 ft above ground won particular approval; and, finally, by a clever and amusing cartoon film showing transport in Canada from the canoes of the Indians to the arrival of a flying saucer from outer space. E. O. T.

RUGBY AND NORTHAMPTON

RUGBY SUB-CENTRE

On to 1955-56

Since the last report from the Sub-Centre in the *Journal*, the 1954–55 session has finished and preparation for 1955–56 is now in hand. The past year has again been successful, thanks to the able Chairmanship of Mr. D. Edmundson. Some meetings have not been as well attended as might have been expected; this is probably due to the many other similar activities which take place in Rugby. Despite this the average attendance at meetings has been well maintained.

The Sub-Centre were pleased to welcome to the meeting on the 1st December, 1954, Dr. Willis Jackson, a Vice-President, who, as reported previously, was unable to attend the opening meeting of the session and came on December 1st instead. Those present were grateful to him for doing so and much appreciated his remarks on Institution matters.

A District Meeting was held at Northampton on the 29th April, 1955, when Mr. R. M. Grant (a member of the Sub-Centre) gave a talk on *Water Power*; this was followed by a colour film showing details of the hydro-electric scheme at the Owen Falls, which was opened by

the Queen last year. The meeting was held at the Plough Hotel and was a very enjoyable function. Thanks are due to the two Northampton Committee members, Mr. E. A. Cross and Mr. W. H. Jones, for making the local arrangements.

On March 25th the ball organized jointly by the Rugby Engineering Society and the Sub-Centre was held at Chesford Grange. Approximately 450 people attended, and a special effort was made to induce the students to attend by reducing the price of their tickets; this was a successful idea, and everyone was pleased to see a good attendance by Student Members. From general comments and reports received the ball appeared to be a complete success.

The officers of the Sub-Centre for the 1955–56 session have now been elected. Mr. L. D. Anscombe will be the new Chairman, and the three new members of the Committee will be Mr. J. H. Fearon, Dr. W. J. Gibbs and Mr. W. S. Melville. Mr. J. H. Cansdale retires from the office of Treasurer, which he has held since the Sub-Centre was formed; he now becomes first Vice-Chairman. Mr. H. Orchard has been elected Treasurer and Mr. W. J. Carfrae second Vice-Chairman. Mr. R. M. Grant, Mr. W. J. Pool and Dr. E. G. Stanford retire from the Committee; the Sub-Centre is grateful to them for their able assistance during their period of service.

E. S. H.

SHEFFIELD

SHEFFIELD SUB-CENTRE

It was with great regret that the Sheffield Sub-Centre Committee learnt of the death of its Treasurer, Mr. W. E. Burnand, on the 24th April, 1955. Mr. Burnand first served on the Committee in 1923 and was Chairman in 1930. He has been Treasurer since 1937. He will indeed be greatly missed by all members of the Sub-Centre and his other friends in Sheffield. His work in aid of the Benevolent Fund—particularly his annual appeals to the Sub-Centre on its behalf—will always be remembered by members in Sheffield.

On the 1st April, 1955, the Sub-Centre held its Annual Dinner-Dance at the Royal Victoria Hotel in Sheffield, where 230 members and guests spent a very enjoyable evening.

The Annual General Meeting was held on April 20th. It had been arranged that Mr. Burnand would read a paper on *Sixty-three Years of Electrical Engineering in Sheffield*, but, ill as he was at the time, he was unable to. Instead, the meeting saw a colour film showing the construction of the Volga–Don canal, which was kindly lent by Mr. C. P. Scott, who led the British mission of businessmen to Moscow last year. This film showed the scope of the scheme, and the construction involved in it, including the various irrigation canals, and all those who saw it were very much impressed by the magnitude of the project. A vote of thanks to Mr. Scott was proposed by Mr. Rewcastle.

G. G. N.

STOKE AND STAFFORD

NORTH STAFFORDSHIRE SUB-CENTRE

At the Stoke meeting on the 11th March, 1955, Mr. D. P. Sayers read the paper on *The Possibilities of a Cross-Channel Power Link between the British and French Supply Systems* by Monsieur M. E. Laborde, Mr. F. J. Lane and himself. This meeting took place soon after a lecture* by Mr. Åke Rusck to the Supply Section in London, which included details of the 100 kV d.c. project for transmission of power by submarine cable to Gottland, and many references to this occurred in the discussion. Mr. Sayers said that the information now available would enable both d.c. and a.c. methods to be included in any further consideration of the cross-Channel link.

Mr. A. R. Buttrey, in proposing a vote of thanks, complimented Mr. Sayers on the way he had dealt with the complex maze of questions which had arisen. He thought it was one of the advantages of the nationalized industry that it could consider such a large project on a broad basis and afford the cost of the full-scale experiments necessary to assess its possibilities accurately. He felt that the work done by Swedish engineers would be a great asset to them; we should be watchful to avoid being left behind in the development of high-voltage d.c. transmission. The paper was followed by a film which vividly indicated the conditions and the difficulties of laying large submarine power cables.

At this meeting a formal welcome was extended to two new Corporate Members. It was also announced that the Hon. Secretary, Mr. W. G. Friggens, had resigned on leaving the district and that his duties would be taken over by Mr. E. Bolton for the remainder of the session. As small credit balances have resulted from the annual dance and dinner of the Sub-Centre, it has been decided to make a donation of ten guineas to the Benevolent Fund. Congratulations have been sent to Sir George H. Nelson and Mr. A. J. C. De Renzi, both of the Sub-Centre, who have been members of The Institution for 50 years.

A joint meeting with the Students' Section was held at Stafford on April 18th, when three short papers were read by students. These were *The Application of Rectifiers to the Supply of D.C. Motors* by Mr. H. Kemp, *The Mathematics of Natural Uranium Reactors* by Mr. R. Larkinson, and *The Axial Air-Gap Motor* by Mr. D. Beith. Mr. J. E. Boul proposed a vote of thanks to the authors and complimented them on their presentation of the papers and the excellent way in which they had dealt with the discussion. He appealed to senior members to encourage Students in every way possible to prepare papers for reading and to take an active interest in The Institution, since its future depended on them.

An Institution prize was presented to Mr. A. Carmon for the high standard attained in the Higher National Diploma examination.

L. G.

* See *Journal*, April, 1955, page 246.

Journal I.E.E., June 1955

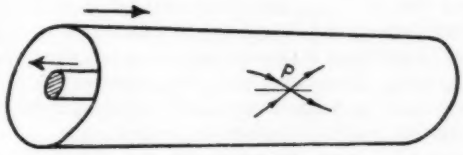
Wire-Braid Screens for R.F. Cables

By W. T. BLACKBAND, M.Sc., *Associate Member*

IN order to achieve complete screening, the current distribution in the outer conductor of a cable must produce a field external to the cable which cancels the external field due to the currents in the inner conductor or conductors. As the flow in the inner conductors is longitudinal, so then should be the compensating currents induced in the outer conductor. For a continuous conductor such as an extruded lead sheath this will be so.

Wire Screen

If the lead sheath were replaced by longitudinal wires laid side by side on the periphery of the cable core, these wires could carry the necessary compensating currents without any current passing from one wire to another at their points of contact. As contact resistance plays no part in the functioning of the screen, such a wire outer-conductor would provide efficient screening even if dirt or corrosion prevented good contact between the separate wires. However, a wire screen of this kind would be impracticable for mechanical reasons, the chief of these being that, as the cable is bent, the outside layers must be capable of lengthening and the inside layers of shortening. If a wire lies helically about the cable the cable can bend easily, because the slack wire from the inside of the bend is taken up in providing the extra wire for the outside of the bend.



1 *Currents in screen of coaxial cable*

Coaxial Cables

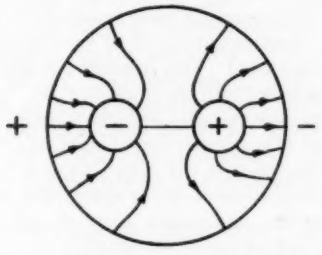
One early design of coaxial cable had a screen of wires applied helically all with the same lay, which of course flexed easily. However, the wire helices could not carry a longitudinal current except by transfer from one wire to another, and for this reason the screening and attenuation properties of this type of cable were variable, being dependent upon the wire-to-wire contact resistance.

The present practice for coaxial cables is to form the outer conductor from a wire braid. Such a braid is woven from equal numbers of wires encircling the cable core in right- and left-hand helices of equal lay length. Because of the helical path of the wires round the cable the screen flexes easily. It can also be shown that its electrical performance should be good. In Fig. 1, consider the two wires which cross at the point P. For perfect screening, the resultant of the two currents carried by the two wires must be longitudinal, and this will be so if the currents in each wire are equal, as from symmetry they must be.* There is then no transfer of current from one wire to another, the contact resistance of the wires has no importance, and corrosion does not affect the performance of the cable braid.

For convenience in the organization of the braiding machines in war time, a certain cable maker sometimes formed braids with different numbers of wires in left- and right-hand helices (for example, seven and five wires respectively). This gave greater conductivity in the one set of helices, and so disturbed the symmetry of the contacts. Such a braid would be expected to be less efficient as a screen than a symmetrically made one.

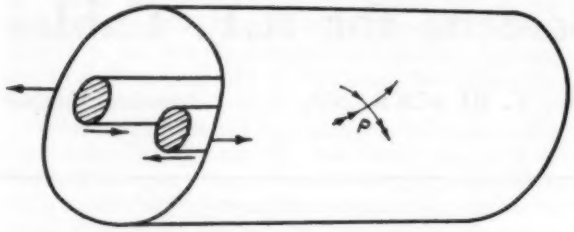
Twin Cables

In a twin cable the contacts between wires play an essential part in the functioning of the screen. From reference to Fig. 2 it will be seen that, because of the field distribution, the currents induced in the screen are greatest near the two conductors, and zero at points equidistant from them. Thus a pair of wires such as



2 *Field in screened twin cable*

* This is true to a first approximation only, because the wire paths are not exactly the same. The path which lies inside the braid offers a slightly lower impedance than that of the wire which crosses it on the outside of the braid. This slight difference between the paths is of practical importance only at the highest frequencies.



3 *Currents in screen of twin cable*

those crossing at the point P of Fig. 3 will not carry equal currents into the contact, the wire running up the page carrying the greater current. If the resultant current is to be longitudinal, the wire leaving P downwards, which previously carried the lesser, must now carry the greater current. This change in current can be achieved only by transfer across the contact resistance between the wires. If this resistance is small the compensating currents in the screen will be nearly longitudinal, and the screening will be good. If the wires were completely insulated from each other they could modify the field due to the inner-conductor current only slightly, thus providing very little screening.

Let us now consider a specific example: the twin cable Duradio No. 11 is a wire-braid-screened version of Duradio No. 14, which is an unscreened twin cable. The effect of the screen on the external field is to make the characteristic impedance of Duradio No. 11 95 ohms, while that of Duradio No. 14 is 140 ohms. It would be expected that contact resistance due to the corrosion of the braid wires would cause an appreciable rise in characteristic impedance as well as a lowering of screening efficiency. Large variations in characteristic impedance and poor screening have been commonly observed in aged braided-screen twin cables, while the corresponding lead-sheathed cables have been stable.

Various methods of minimizing these variations have been used. One favoured in Britain is to lap a metal-foil tape beneath the braid in order to provide a low resistance path in parallel with the contact resistance. The efficacy of this remedy for instability depends upon the life of the foil. If the cable is flexed violently the foil may be torn without there being any apparent damage to the cable, and when torn it will play little part in the functioning of the screen.

Twisted Inner Conductors

If the inner conductors of the twin-cable core are twisted, as is in fact the usual construction, the compensating currents in the screen should be helical with the same lay length as for the inner conductors. One method of improving stability would be to apply the braid with the same lay. In this method one set of wires would lie along the ideal path for the compensating currents and so would be ideally placed for screening—however, their good work would be spoilt by the transfer to them of currents from the second set of wires, which in general would also carry induced currents. The ill effect of the second set of wires could be avoided in a number of ways. A simple method would be to construct the braid of enamelled wire so that no disturbing currents could be transferred from the second set of wires. Another method would be to design the cable so that while the braid wires had the same lay as the twisted conductors, they crossed at right angles. In this arrangement no currents would be induced in the second set of wires, which would be normal to the current flow.

Conclusion

The essential difference between the screening of coaxial and twin cables is that in the former the currents are induced uniformly over the screen surface, while in the twin cable all parts of the screen are not equally loaded. If the inner conductor of a coaxial cable were displaced from the cable axis, the current in the near part of the braid would be increased at the expense of that on the other side of the screen; the braid efficiency would then become dependent upon the wire contact resistances, although the effect would not be so marked as in the case of twin cables. From these considerations we see that if, in a braid-screened cable with several insulated cores, the screening of any one circuit is of special importance it should use a central rather than an outside core. This is because the compensating currents for a central core are evenly distributed over the braid, and contact resistance effects are minimized.

Acknowledgment is made to the Chief Scientist, Ministry of Supply, and to the Controller of H.M. Stationery Office, for permission to publish this article.

OVERSEA ATTENDANCE REGISTER

During the period 1st March to 30th April, 1955, the following members called at the Institution building and signed the Attendance Register of Oversea Members:

BARNES, P. McC. (Christchurch, New Zealand).
BARTHOLOMEW, B. C., B.Sc. (Lagos).
BARTLETT, G. L., B.E. (Dunedin, New Zealand).
BUNDELL, J. H. (Perth).
CANDY, P. W. K., B.Sc.(Eng.) (Johannesburg).
COWIE, W. S., B.Sc. (Ipoh, Malaya).
DEGLON, C. R., B.Sc.(Eng.) (Salisbury, Southern Rhodesia).
FITTON, T. W. E. (Takoradi, Gold Coast).
GRAY, J. (Penang).
GRIPPER, H. J., B.Sc. (Port Elizabeth).
HAYWARD, G. O. (Gold Coast).
HENLEY, J. H., B.Sc. (Nelson, New Zealand).
HOOPER, D. E. (Melbourne).
LINEKER, A. W., B.Sc. (Johannesburg).
MARSHALL, H. W. S. (Kirkuk, Iraq).
MEIER, G. A. (Zürich).
MITCHELL, J. E., B.Sc.Tech. (Salisbury, Southern Rhodesia).
PARLOUR, J. H. (Nairobi).
PEREIRA, J. de A. (Lisbon).
SCHOTANUS À STERINGA IDZERDA, H. H., Dipl.Ing. (Delft, Holland).
SINGH, H., B.Sc. (Delhi).
VAUGHAN, J. (Ijora, Nigeria).

NEWS *from abroad*

HERE AND THERE

Among those we have been pleased to welcome recently at Savoy Place are Mr. R. W. Parsons, Principal of the South Australian School of Mines and Industry and President-Elect of The Institution of Engineers, Australia; Mr. A. B. Cowen, the Oversea Representative of the Council for Rhodesia, who managed to find time in the course of a fleeting visit to the United Kingdom to visit The Institution's Headquarters; Mr. C. R. Deglon, from Salisbury, Rhodesia; Mr. J. E. Mitchell, also from Salisbury, and a Member of the Council of the Rhodesian Institution of Engineers; and Dr. H. D. Einhorn from the University of Capetown.

Mr. R. P. Horlock called to see the Secretary before he left with his family for Canada, where he is taking up an appointment in Hamilton as Manager for Canada of the Metropolitan-Vickers Electrical Export Co. Mr. Horlock was formerly Manager of the company's Sheffield office and has for long been associated with the North Midland Centre Committee, of which he was Chairman in 1948–49; our best wishes go with him and his family for their new life in Canada.

Senior members whose duties have taken them abroad recently include Sir Hamish MacLaren, Member of Council, who is visiting the United States and Canada; Dr. L. G. Brazier, immediate Past-Chairman of the Supply Section, who is attending the Annual Meeting at Toronto of the Engineering Institute of Canada, where he will be reading a paper on *Power Transmission by Underground Cables*; and Dr. J. H. Westcott, Member of Council, who has visited the United States.

MIDDLE EAST

The Iraq and Persian Gulf Joint Oversea Group met in Kuwait on the 17th and 18th February, 1955. There was a good attendance and the meeting was privileged to hear an address from Mr. A. C. Hartley, a Past-President of The Institution of Mechanical Engineers, who also conveyed the good wishes of the Presidents of the three Institutions.

Mr. Hartley was invited to attend the Committee meeting of the Group prior to the meeting, and his advice was greatly appreciated. He and Mrs. Hartley were the guests of the Group at a cocktail party held at the Basrah Airport Hotel on March 1st.

The next meeting of the Group was held in March in Baghdad, at the Saadun premises of the Iraqi Society of Engineers; it was attended by 40 members, eight of whom came from Kuwait and several others, including the Group's Chairman, Mr. R. C. Kelt, from Basrah. Sayid K. Kouyoumdjian, mains engineer of the Baghdad Light and Power Co., gave a competent general survey of the difficulties of Baghdad's power supply—with an outline of its history since the end of the First World War, as a background. The talk was illustrated by lantern slides and a colour film, and was followed by a discussion in which most of the audience took part.

The Baghdad meeting included a tour of the Dora oil refinery, at which Mr. J. Diesenroth, of the Kellogg International Corporation, explained the operation of the plant. Sayid Niazi Fetto, a Vice-Chairman of the Group, was host to the visitors at a luncheon at the Mansur Club after the meeting.

The Iraq and Persian Gulf Group has been very active in the two years of its existence as a vehicle for gathering information about problems of common interest to engineers working in the Middle East and for providing opportunities for them to meet and discuss such problems. Membership of the Group is open, without any extra subscription, to members of The Institutions of Civil, Mechanical and Electrical Engineers who are resident in Iraq and the Persian Gulf territories. Those desiring further information are asked to get in touch with Mr. R. C. Kelt, c/o Port Directorate, Basrah, or with Sayid Niazi Fetto, Baghdad.

J. M. M.

NEAR EAST

Near East members have been lucky in having the opportunity of hearing a talk on *Sound Broadcasting* by Dr. K. R. Sturley, who has been visiting the area. His talk was given at Kirkuk on the 30th March, 1955, at Beirut on April 4th (by arrangement of the British Council, at the American University) and at Tripoli, Lebanon, on the next day. This talk, illustrated by lantern slides and by tape recordings, was open on each occasion to the public, and the keen response showed the interest taken locally in sound broadcasting. In the somewhat isolated communities in oil-field and pipe-line areas, radio reception and gramophone reproduction are a great boon, and there is a more than usual desire for good-quality reproduction. Dr. Sturley was introduced in each place by the Oversea Representative of the Council, Mr. A. G. Coates.

On April 2nd, members resident in Tripoli, with their wives, had the opportunity of meeting Dr. Sturley at a cocktail party. This small function was a very pleasant occasion, reminding some members of The Institution's Conversaziones—on a greatly reduced scale!

It is hoped that other distinguished members of The Institution who visit the Near East will make themselves known to the Oversea Representative, particularly if they would be agreeable to read a paper or give a talk during their tour; members in the area are particularly grateful to Dr. Sturley, and would like to hear other speakers.

A. G. C.

DIGESTS *of Papers in the Proceedings*

The Adhesion of Electric Locomotives

A DIGEST OF A NON-SECTION PAPER (No. 1797) WITH THE ABOVE TITLE, BY H. I. ANDREWS, PH.D., M.SC., M.I.MECH.E., MEMBER. THE FULL PAPER WAS PUBLISHED SEPARATELY IN APRIL, 1955, AND IT WILL BE REPUBLISHED IN PART A OF THE PROCEEDINGS.

THE POWER applied to each driving axle of modern electric locomotives is steadily tending to increase, with the result that the adhesion between the wheels and the rails is rapidly becoming the "bottleneck" of design. This has been particularly experienced by British Railways in the working of the severe Wentworth incline, on the recently opened Manchester–Sheffield–Wath electrification, which has a maximum gradient of 1 in 40. It was therefore decided to investigate the limiting adhesion of the $B_0 + B_0$ locomotives working this incline, and measurements were made as follows:

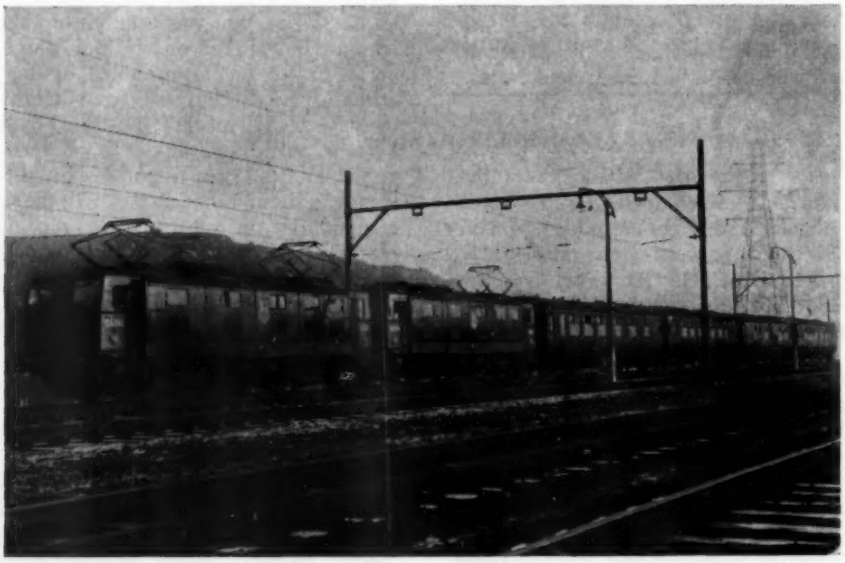
(*a*) On one axle of a locomotive under constant working conditions.
(*b*) On a normal locomotive working at various values of constant speed.
(*c*) On two locomotives in service.

Measurements were made on the line under controlled conditions with the mobile testing plant—a special train which combines the instrumentation of a dynamometer car with an electronically regulated electric braking system. The first series of tests were made on one axle of a temporarily modified locomotive, the tractive effort of which could be finely adjusted. The test train, shown in Fig. 1, comprised a hauling locomotive, the test locomotive, the dynamometer and control car, and three electric braking units. During running at constant speed the tractive effort applied to the test axle was gradually increased until slipping occurred, as indicated by a suitable instrument, and the corresponding tractive effort was calculated from a record of the current in the motor.

For the second series of tests a locomotive in normal condition was attached to the mobile testing plant (Fig. 2), and tested at full load at various values of constant speed. Slipping of any axle was again indicated and related to the tractive effort calculated from records of the motor currents.

In the third series, trains of 850 tons were hauled by two locomotives up the Wentworth incline, one locomotive working as train engine and the other as banker. A considerable number of such trials were made in different weather and other circumstances, and the conditions under which slipping of the locomotives occurred were recorded by two dynamometer cars, one at each end of the train.

It was found that the limiting adhesion was primarily affected by the amount of water present on the head of



1 *Measurement of adhesion under constant working conditions*

Hauling locomotive, test locomotive and mobile testing plant; measurements made on second axle of test locomotive.

the rail, and by some factor associated with the permanent way. There was an apparent decrease of adhesion at higher speeds, which might seriously affect the performance of high-power locomotives in passenger service.

2 *Measurement of adhesion of normal locomotive at constant speed*
Locomotive No. 26030 with mobile testing plant.

Experiments were made with methods of improving adhesion, including the use of sand, which seemed irregular in action, and of certain ester solutions, which gave promising results.

Certain inconsistencies in the results suggested that there might be variation in the axle loads during running.

3 *Measurement of load on axle-boxes*
Spring hangers employed as electrical weighing elements.

This was investigated by fitting the locomotives with special spring hangers (Fig. 3) made up as the working elements of an electrical weighing system, described in a previous paper,* so that the loads on the axle-boxes could be indicated in the dynamometer car. It was found that there were temporary variations of as much as 4 tons from a nominal axle load of 21 tons, and these variations are probably the explanation of many peculiarities found in this and other investigations.

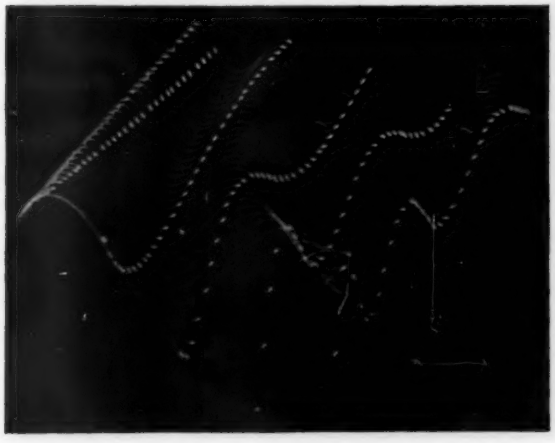
As an immediate result of this work it has been possible to prepare modified driving instructions which are of considerable benefit under difficult conditions, and certain locomotives have been fitted with a vernier notching control which is found to increase the adhesion performance by as much as 6%.

* ANDREWS, H. I.: "Electrical Weighing," *Proceedings I.E.E.*, Paper No. 894 M (1950, 97, Part I, p. 98).

High-Speed Computation

A DIGEST OF A MEASUREMENTS SECTION PAPER (No. 1738 ENTITLED "HIGH-SPEED ELECTRONIC-ANALOGUE COMPUTING TECHNIQUES," BY D. M. MACKAY, B.SC., PH.D). THE FULL PAPER WAS PUBLISHED SEPARATELY IN OCTOBER, 1954, AND IT WILL BE REPUBLISHED IN PART B OF THE PROCEEDINGS.

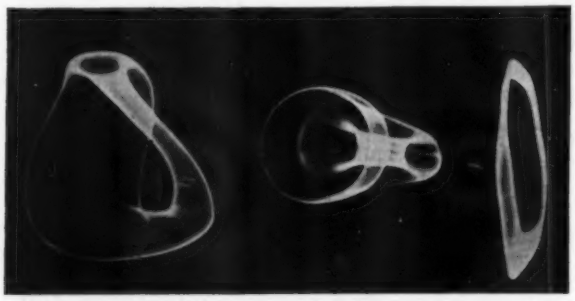
WHAT ARE THE LIMITS to the speed at which an electronic differential analyser can function? The paper describes some results (up to 1950) of a research programme designed to explore this question. The problem of high-speed computation is fundamentally twofold: to make the apparatus work fast enough, and to follow and control its activities at the same speed. There is little difficulty in integrating and adding variables electronically at any required speed, but it is less easy to multiply two rapidly changing variables, or to generate arbitrary functions in a few tens of microseconds. For the present computer a multiplier has been developed which shows negligible phase-shift up to 50 kc/s, using



1 *Solutions of the s.h.m. equation* $\ddot{y} + \omega^2 y = 0$ *for 32 values of* ω^2

square-law amplifiers of a novel design. Networks using biased diodes have proved satisfactory for the approximate synthesis of arbitrary functions of an input variable at correspondingly high speeds.

Electronic switching circuits have been devised which can set initial conditions, and change automatically the parameters in successive runs, at rates up to 25 000 solutions per second. With the present apparatus 32×32 different equations can be successively solved in a total time which may, at the sacrifice of some accuracy, be made as short as 1/25 sec.



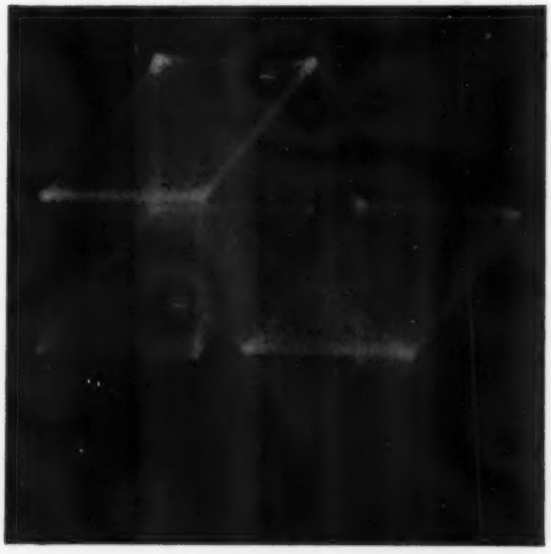
(*a*) (*b*) (*c*)

2 *The 4-dimensional Klein bottle*

(*a*) Side view of 3-dimensional projection.
(*b*) Top view of 3-dimensional projection.
(*c*) Projection on the fourth dimension; the neck may be seen to reunite with the body without intersecting it.

Such high speeds are obviously useless unless the results can be presented in a way which enables successive solutions to be distinguished and correlated with the parameters being varied. To this end, multi-dimensional displays have been developed, in which a cathode-ray tube shows successive solutions as if displaced side-by-side in a 3-dimensional or 4-dimensional space. This enables the operator to see at a glance the trend of a solution with a given parameter (Fig. 1). The ambiguities of the 2-dimensional projection on the screen are resolved by altering electrically the angles of projection. Fig. 2, for example, shows three orthogonal projections of the notorious Klein bottle—a single-sided surface which cannot be constructed in three dimensions without intersecting itself, but which can avoid this restriction in four dimensions, as Fig. 2(*c*) shows. The 4-dimensional figure was generated by solving electronically its parametric equation. Fig. 3 shows a projection of a tesseract or 4-dimensional analogue of the cube.

In conclusion it may be said that for suitable problems, where accuracies better than 1% are not required, such analogue techniques make possible extremely rapid and flexible processes of trial and error, with an improvement in information capacity up to a thousandfold over conventional methods.



3 *Projection of a tesseract, showing* (inter alia) *planes meeting only in one point*

Artificial Reverberation

A DIGEST OF A RADIO SECTION PAPER (No. 1796) WITH THE ABOVE TITLE BY P. E. AXON, O.B.E., M.SC., PH.D., C. L. S. GILFORD, M.SC., F.INST.P., AND D. E. L. SHORTER, B.SC.(ENG.), ASSOCIATE MEMBERS. THE FULL PAPER WAS PUBLISHED SEPARATELY IN FEBRUARY, 1955, AND IT WILL BE REPUBLISHED IN PART B OF THE PROCEEDINGS.

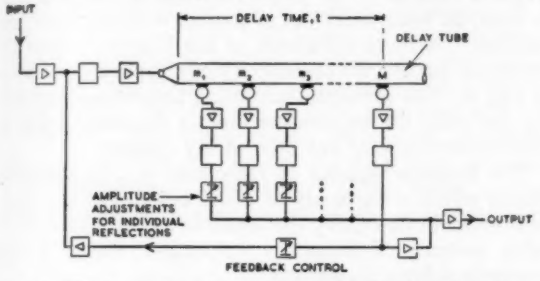
THE QUALITY of the sound transmitted from a broadcasting or sound-recording studio depends very much on the natural reverberation characteristics of the studio. It is often desirable to supplement the natural reverberation by artificial reverberation obtained by modifying the electrical output from the microphone chain in the studio.

The commonest method of achieving the desired result is to reproduce the signal from the studio microphone by a loudspeaker situated in a bare-walled reverberation room; the resulting sound, which is then very "reverberant," is picked up by an auxiliary microphone, the output of which is added to the outgoing signal (due precautions being taken against unwanted feedback). Reverberation rooms occupy valuable building space and must for economic reasons be of relatively small dimensions; unfortunately, the quality of the reverberant sound in a small room is less pleasing to the ear than that produced by a large room having the same reverberation time, and the result is not entirely satisfactory for all types of programme.

Alternative forms of artificial reverberation depend on the use of some form of time-delay system involving transmission in one dimension only, by which the original signal is repeated again and again with pro-

gressively decreasing amplitude. Each repetition represents a reflection from the boundaries of an imaginary room, and may therefore be described as an artificial reflection; the complete series then constitutes artificial reverberation. By the use of overall feedback the signal may be made to traverse the delay system repeatedly, and the series of reflections is thus indefinitely prolonged.

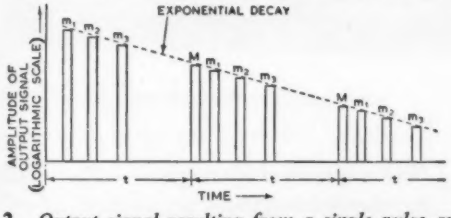
Fig. 1 shows in diagrammatic form a workable arrange-



1 *Artificial reverberation system using single delay channel with several outlets; feedback over single path*

ment of this kind, using as the delay element an acoustic transmission tube in which sound from a loudspeaker is picked up by a number of microphones. Fig. 2 shows the series of artificial reflections resulting from a single incoming pulse. The microphones should be spaced at irregular intervals along the tube to avoid forming a periodic series of reflections, or a "coloration" of characteristic pitch will be imposed on the signal. Furthermore, unless the average interval is so short that individual reflections cannot be distinguished by the ear, a transient sound, such as a handclap, will produce an effect of amplitude flutter.

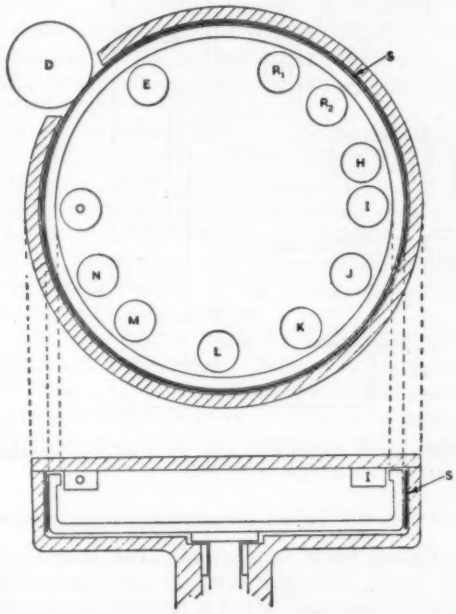
To obtain the maximum reverberation time with a given delay channel, the attenuation in the feedback loop,



2 *Output signal resulting from a single pulse applied to the artificial reverberation system shown in Fig.* 1

which represents the margin of safety from self-oscillation, must be made as small as possible; stringent requirements are thus imposed on the gain stability and frequency characteristics of the circuit.

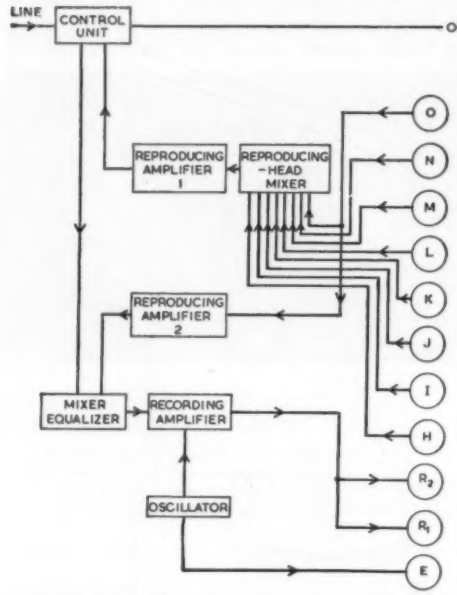
Acoustic delay systems, while simple in principle, involve many instrumental complications which arise in part from the natural imperfections of microphones and loudspeakers and in part from the heavy attenuation of sound in tubes. High-quality artificial reverberation can be better and more economically produced by employing a magnetic recording system to give the necessary time lag. Here the delay may be obtained by recording the programme signals on a rotating drum or wheel which is coated with the recording medium. The programme is then reproduced at subsequent intervals by a series of reproducing heads spaced around the periphery of the drum or wheel. In this system there is no fundamental attenuation of the programme signals in the delay unit, i.e. the voltage induced in a reproducing head is inde-



3 *Mechanical arrangement of magnetic-recording delay unit*

pendent of its distance from the recording head, so that the basic delay which can conveniently be obtained is much larger than in the tube system. Here, too, a feedback system can be used in order to increase the effective delay time still more. To give a realistic impression and diminish the flutter effects which may occur on transient sounds, the delay unit should produce a large number of randomly spaced reflections in a short time. This would normally imply that a large number of reproducing heads should be employed, but an alternative, and more economical, system using multi-track recording has been developed. Fig. 3 shows a section and a plan of the delay unit in a B.B.C. equipment. R_1 and R_2 are two recording heads, each recording the programme signal on two tracks situated one above the other on the inner periphery of a basin-shaped wheel. The wheel has an inner diameter of $9\frac{1}{2}$in and is rotating at about 3rev/sec. H, I, J, . . . N are seven reproducing heads, irregularly spaced around the periphery, which span both recorded tracks and reproduce signals from them simultaneously.

Since the recorded tracks are displaced longitudinally, each reproducing head produces every signal in the programme twice during one rotation of the wheel, so that the effective number of reflections provided by the seven reproducing heads is fourteen. The outputs of the various heads are attenuated so that successive reflections fall in amplitude along a smooth exponential curve corresponding to the reverberation time being simulated. O is a feedback head which feeds the signal from the lower track into the general output and also back into the recording heads at such a level that the decay is carried smoothly on until noise level is reached. The use of a feedback head spanning both tracks, although increasing the number of reflections generated, may be shown to introduce another type of amplitude flutter so that single-track feedback is employed. E is an erase head which erases the signal from both tracks leaving them ready for fresh recording by the recording heads in each revolution. To avoid the necessity of frequent renewal of the magnetic tracks and heads, due to wear, all heads work out of contact with the recording medium. A block schematic of the interconnection of the delay unit and the associated electronic units is shown in Fig. 4. The principles governing this interconnection are the same for an acoustic tube, a magnetic delay, a reverberant room or any other delay system.



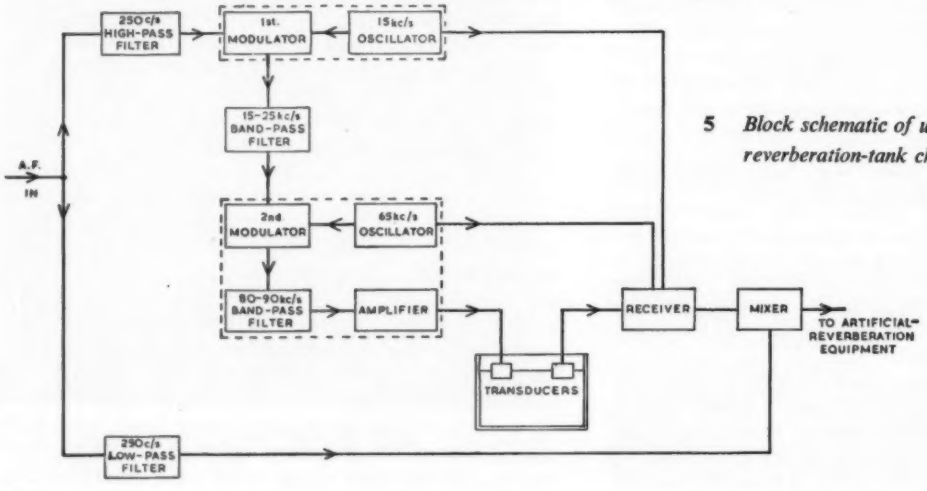
4 *Simplified block schematic of artificial-reverberation equipment*

The irregular spacing of reflections (i.e. reproducing heads) which is necessary to avoid coloration has been mentioned in describing the acoustic tube system. Two other sources of frequency coloration exist in the magnetic delay unit, namely

(*a*) That which arises when the signal voltages induced in each reproducing head from the two recorded tracks are in phase.
(*b*) That which arises when signal voltage from the feedback head is in phase with the voltage applied to it from the programme chain.

The various frequencies at which these colorations occur are determined by the recorded wavelengths and the head spacings. The latter may be arranged, in a sufficiently complex system such as the present one, so that no unacceptable frequency colorations are produced in the most frequently required range of reverberation times.

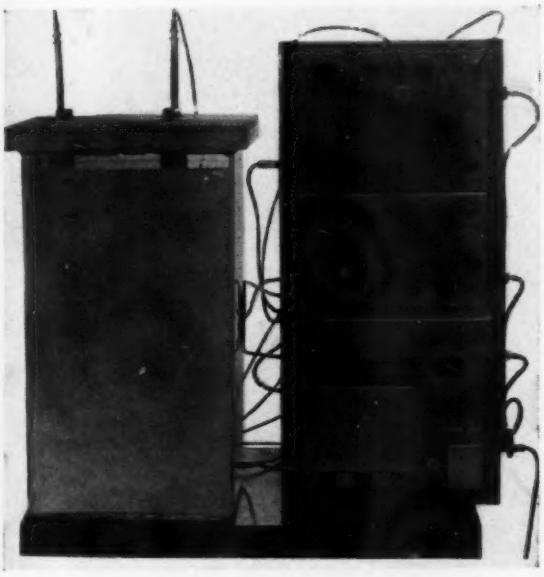
Even in the multi-track system the problem of amplitude flutter still remains when dealing with some transient programme sounds such as pistol shots. The quality of the output can be greatly improved in this respect by first passing the programme signals through a small room which adds enough reflections to fill in the intervals between the signals from the reproducing heads. Such



5 *Block schematic of ultrasonic-reverberation-tank chain*

an arrangement is, of course, inconvenient, and a method of doing the same thing with transportable apparatus is required.

After some experiments with scale models filled with heavy gases, it was decided that the requirements could be met most easily by passing the programme as a modulated ultrasonic carrier through a tank filled with water. The signals are introduced into the tank through a barium titanate crystal transducer at the surface of the water, and are picked up as multiple reflections by a similar transducer. The high velocity of sound in water ensures a very large number of reflections, and a high ultrasonic carrier frequency is chosen so that all the dimensions of the tank can be large compared with the wavelength. This minimizes the colorations caused by the establishment of strong standing-wave patterns. The low-frequency components of the signal do not contribute to the flutter effect in the magnetic delay



6 *Ultrasonic-reverberation-tank apparatus*

(their period being longer than the average effective spacing between reproduced reflections), but are more seriously affected than the higher frequencies by standing-wave effects in the tank; the original signal is therefore separated by complementary 250c/s low- and high-pass filters into two frequency bands, only the high frequencies being passed through the ultrasonic system. Fig. 5 is a schematic of the ultrasonic system. A single-sideband modulation system was found necessary to avoid a distortion akin to the selective fading of radio signals.

Fig. 6 is a photograph of the prototype ultrasonic apparatus, showing the glass tank, the barium titanate transducers and the associated electronic equipment.

Testing Large Circuit-Breakers

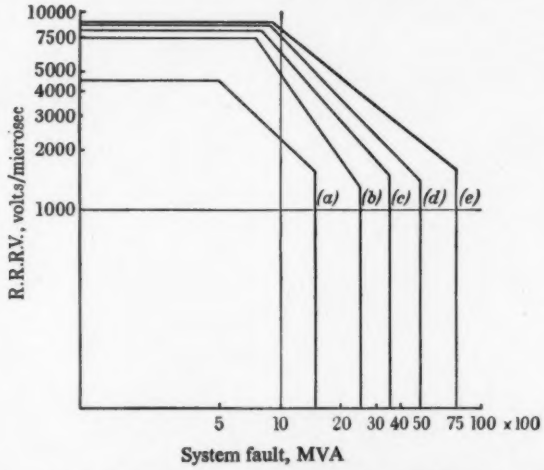
A DIGEST OF TWO SUPPLY SECTION PAPERS (Nos. 1707 AND 1736) ENTITLED "PROVING THE PERFORMANCE OF CIRCUIT-BREAKERS, WITH PARTICULAR REFERENCE TO THOSE OF LARGE BREAKING CAPACITY," BY J. CHRISTIE, M.I.MECH.E., MEMBER, H. LEYBURN, B.SC.(ENG.), MEMBER, AND J. F. BIRD, M.C., T.D., B.SC., ASSOCIATE MEMBER, AND "A NEW TESTING STATION FOR HIGH-POWER CIRCUIT-BREAKERS," BY J. CHRISTIE, M.I.MECH.E., MEMBER, H. LEYBURN, B.SC.(ENG.), MEMBER, AND R. W. FENN, M.ENG., A.M.I.MECH.E., ASSOCIATE MEMBER. THE FULL PAPERS WERE PUBLISHED SEPARATELY IN AUGUST AND DECEMBER, 1954, RESPECTIVELY, AND THEY WILL BE RE-PUBLISHED IN PART A OF THE PROCEEDINGS.

THESE TWO PAPERS are to a large extent complementary, in that both are concerned mainly with large circuit-breakers. The first paper gives a review of present-day testing methods and suggests various ways in which the testing of such circuit-breakers might be improved; the second describes a new testing station which has been designed to provide, so far as is economically possible, the testing facilities needed.

The only proper basis for testing is the conditions which occur in service. These may be classified under two broad headings, namely short-circuit conditions and normal-service conditions, and the main factors affecting the performance of circuit-breakers under these two sets of conditions are analysed in the first paper.

Short-Circuit Conditions and Tests

While much work has been done, particularly by the Association of Short-Circuit Testing Authorities



1 *Envelope curves showing the maximum values of r.r.r.v. which are liable to occur under practical conditions with different values of system fault power*

(*a*) 66kV systems.
(*b*) 110kV systems.
(*c*) 132kV systems.
(*d*) 220kV systems.
(*e*) 275kV systems.

(A.S.T.A.), to lay down rules for circuit-breaker testing, a number of items still remain to be settled. One of these is standardization of the rate of rise of restriking voltage (r.r.r.v.). A study of various power systems has produced the curves in Fig. 1, and from these the suggested standard values for rating and testing, given in the Table, have been derived.

Service voltage	R.R.R.V. at the given percentages of rated breaking capacity		
	30%	60%	100%
kV	kV/μs	kV/μs	kV/μs
66	5	2·5	1·5
110	7	2·5	1·5
132	7	2·5	1·5
220	7	2·5	1·5
275	7	2·5	1·5

Other items require further consideration: for example, amplitude factor, which needs to be standardized, and the asymmetrical current test, which at present is not entirely satisfactory; in many cases it could be omitted altogether and, where it is required, it should be specified more precisely.

One of the main problems in short-circuit testing is how to test circuit-breakers with a larger 3-phase breaking capacity than the output of the available testing stations. The best solution lies in single-phase testing, which enables a larger equivalent 3-phase output to be obtained from a given plant, and in unit testing.

Although single-phase tests are generally equivalent to 3-phase tests, they introduce certain problems of their own, mainly with regard to voltage. At present the single-phase recovery voltage is required to be $1{\cdot}5V/\sqrt{3}$ (where V is the rated voltage), irrespective of the method of earthing of the system for which the circuit-breaker is intended. For circuit-breakers intended for use in multiple solidly-earthed systems, however, there are strong reasons why this should be reduced to $V/\sqrt{3}$ or possibly $1{\cdot}2V/\sqrt{3}$.

Unit testing is a valid method, provided that precautions are taken to ensure that the severity of the test applied to the proportion of units being tested corresponds with the performance to be expected of this proportion. A.S.T.A. Publication No. 15, the issue of which was foreshadowed in the paper, establishes the general procedure for such tests.

Another type of problem is the extent to which allowance need be made for all the extreme conditions which can occur in service. If all were taken into account, testing would get quite out of hand and an uneconomical circuit-breaker would result. One example of this relates to loss of synchronism between power stations. This may in extreme, though unlikely, circumstances impose a duty upon the circuit-breaker in the tie line of 50% rated short-circuit current and over 200% phase-to-neutral voltage; nevertheless a test at 25% current and 200% voltage is quite adequate for all practical purposes.

Normal-Service Conditions and Tests

By far the most important normal-service system conditions are the interruption of transformer magnetizing currents and line charging currents. Both are capable, in certain circumstances, of producing relatively high voltage-surges which may cause flashover or damage to connected equipment.

Upper limits for permissible voltage surges have not yet been agreed and will probably vary somewhat with voltage. It is expected that they will be of the order of 5 times the normal phase-to-neutral voltage in the 3·3–11 kV range, 4·5 times in the 22–100 kV range, and 4 times above 100 kV.

It is not always possible in testing stations to reproduce adequately normal-service conditions, and where this cannot be done tests should be made on a comparative basis. For this purpose a reference circuit-breaker should be tested, first in service for the duty in question and then in the circuit available at the testing station. The performance of the test circuit-breaker in the same testing-station circuit can then be compared with it.

Testing Facilities

When considering what testing facilities to provide to meet the above requirements, particularly for short-circuit conditions, field testing and synthetic testing could be accepted as useful adjuncts only. To make it economically possible to do comprehensive research, development and proving tests it was decided to provide a testing station with sufficient output for full-scale single-phase tests or unit tests on any circuit-breaker needed to meet system requirements in the foreseeable future. A description of the main features of this testing station forms the subject-matter of the second paper.

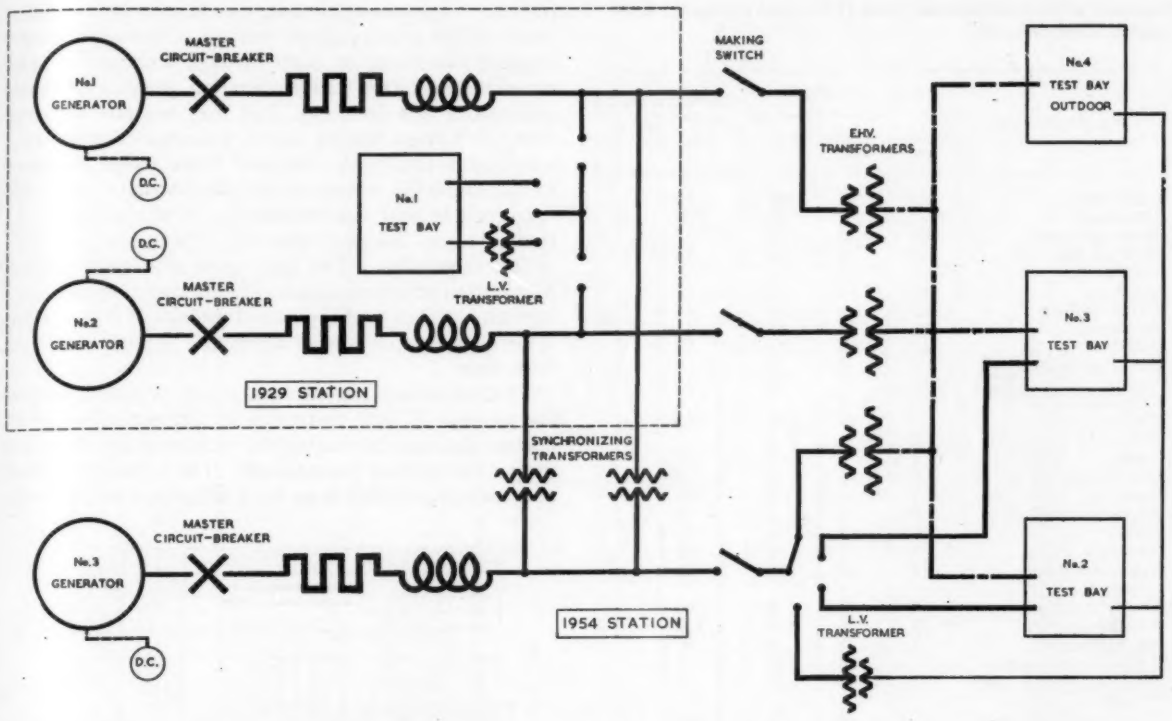
A New High-Power Testing Station

The new testing station was based upon an older existing station and as much use as possible was made of the available equipment. The main additions in the way of power equipment were a third generator and three very large e.h.v. power transformers; the latter have been described in a paper by Rippon.* The electrical layout is shown in Fig. 2.

One of the main aims was to obtain a high single-phase output at high voltages. With a few exceptions, the equivalent 3-phase outputs, obtained single-phase, at the standard rated voltages from 66 to 380 kV are 3 200 MVA with a recovery voltage of $1{\cdot}5V/\sqrt{3}$ and 4 800 MVA with a recovery voltage $V/\sqrt{3}$.

The paper goes on to describe how these outputs were obtained, namely by the use of three generators running in parallel; the control of asymmetry of the applied short-circuit current; the employment of "over-excitation" (as distinct from the more commonly used super-excitation); and the use of the U-connection

* Rippon, E. C.: "Design and Constructional Features of a 275-kV Special-Duty Transformer Bank," *Proceedings I.E.E.*, Paper No. 1690 S, August, 1954 (101, Part II, p. 431).



2 *Electrical layout of old and new testing stations. Simplified single-line schematic*

——— Generator voltage. ——— Low-voltage a.c.
– – – Extra high voltage. ----- Low-voltage d.c.

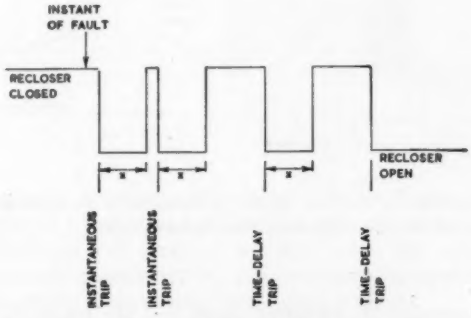
together with over-excitation for increasing the single-phase outputs at standard voltages. It is shown how some of the major problems were solved and the leading particulars of the main items of equipment are given.

Automatic Circuit Reclosers

A DIGEST OF A SUPPLY SECTION PAPER (No. 1717) WITH THE ABOVE TITLE BY G. F. PEIRSON, MEMBER, A. H. POLLARD, B.SC., ASSOCIATE MEMBER, AND N. CARE, MEMBER. THE FULL PAPER WAS PUBLISHED SEPARATELY IN JANUARY, 1955, AND IT WILL BE REPUBLISHED IN PART A OF THE PROCEEDINGS.

THE PAPER describes automatic circuit reclosers of both British and American manufacture and explains the advantages which can be obtained by their use on rural high-voltage overhead-line systems in reducing the time of interruption of supply to consumers.

The Table on page 374 summarizes the types of fault occurring on typical networks; this shows that the majority of faults are of a transient nature; and that if high-speed circuit interruption and reclosure could be provided to prevent transient faults causing fuses to operate, reduced outage time would result.



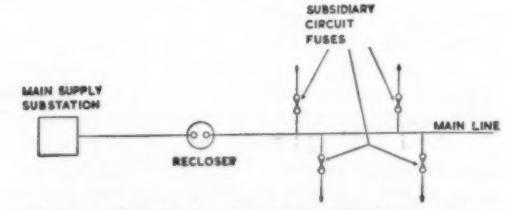
1 *Operating cycle of lock-open recloser*

Open-circuit time x can be selected between the limits 0·25 and 1·0sec.

Fig. 1 shows the operating cycle of a lock-open recloser; it is felt that reclosers of this type have operating characteristics best suited to the requirements of this country. These reclosers should be installed to protect the high-voltage network, as shown in Fig. 2, since by

Summary of Interruptions on Rural H.V. Lines during the Year Ending December, 1953

Cause of interruption	Number of interruptions			Transient faults as percentage of total due to this cause
	Transient	Permanent	Total	
Lightning	423	65	488	86·6
Unknown	193	0	193	100
Birds mid-span ..	80	6	86	93·0
Birds at pole	58	4	62	93·6
Cables	0	7	7	0
Gales	43	10	53	81·2
Cattle rubbing ..	32	3	35	91·4
Insulators	21	28	49	42·9
Accident	14	12	26	53·9
Switchgear (s/station)	0	2	2	0
Vermin	13	1	14	92·9
Corrosion	0	1	1	0
Deterioration ..	9	29	38	23·7
Cable end-box (pole)	0	3	3	0
Trees	6	1	7	85·8
Conductors	0	6	6	0
Surge	5	0	5	100
Faulty manufacture ..	0	2	2	0
Malice	5	13	18	27·8
Sleet and ice	5	3	8	62·5
Line switch and fusegear	4	12	16	25·0
Faulty operation ..	3	2	5	60·0
Switchgear (pole) ..	2	0	2	100
Miscellaneous ..	2	2	4	50·0
Transformer (mains)	2	26	28	7·2
Binders, clamps and jumpers	1	14	15	6·7
Fault on consumers' apparatus	1	0	1	100
Ingress of moisture ..	0	4	4	0
Grand Totals ..	922	256	1 178	78·2



2 *Recloser of the lock-open type installed in the main supply network with subsidiary lines fuse-protected*

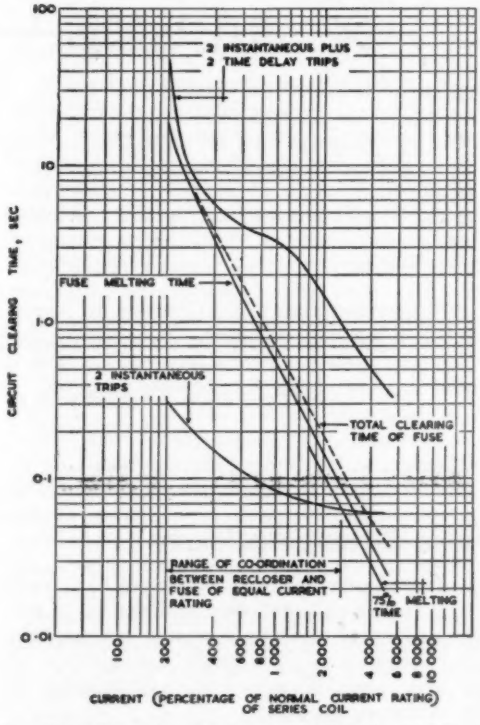
this method all transient faults on the whole of the network past the recloser are cleared without any serious interruption of supply, only a flicker indicating that operation of the recloser has taken place.

The operation of the recloser is automatic, and if, owing to the non-persistence of the fault, operation is stopped at any time during the cycle shown in Fig. 1, the mechanism is arranged to return to its normal position independent of the point in the operating cycle which has been reached. The open-circuit time (x in Fig. 1) may be selected for given reclosers.

It has been found in practice that an open-circuit time interval of approximately 1 sec should meet most requirements in this country, since intervals of this order permit rotating machinery to coast through without the associated under-voltage release operating, whereas very short intervals of less than, say, $\frac{1}{4}$sec may not give sufficient time for foreign bodies, straw, branches of trees, etc., which often initiate the transient faults, to fall clear and so may cause the recloser to operate through to lock-out.

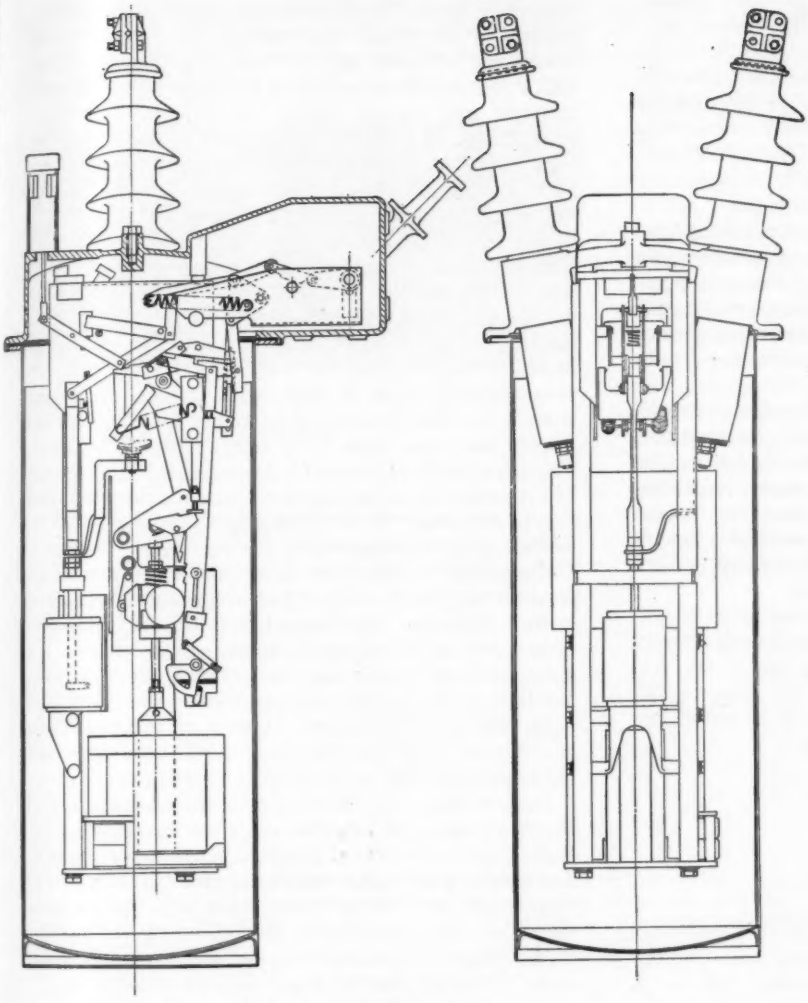
In order to deal with transient faults without deterioration of fuses, the high-speed trip operations are made as fast as possible. Two high-speed trip operations are provided to permit clearance of faults caused by repetitive lightning strokes, and the second passage of fault current sometimes gives a further chance to foreign bodies to burn clear.

Two time-delay trip operations are provided, so that the passage of fault current is of sufficient duration to operate the fuses protecting the section of line on which the permanent fault has occurred. The second time-delay operation is provided as an extra safeguard where, owing

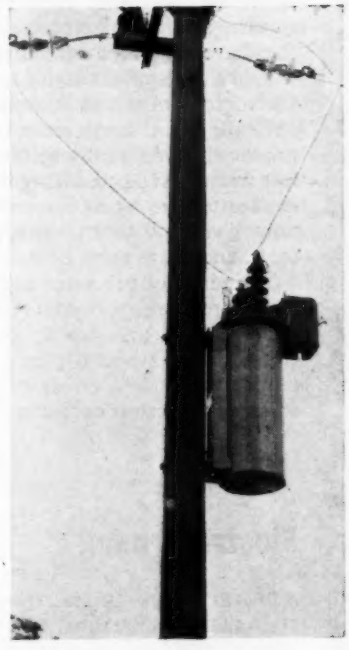


3 *Operating characteristics of British 11-kV automatic circuit recloser*

to the limitation of fault current, accurate discrimination with fuses cannot be obtained on the first time-delay trip operation. To meet these operating requirements, fuses having relatively slow melting characteristics have been developed. Fig. 3 shows the relationship between the



4 *Cross-section of British lock-open-type recloser*



5 *British recloser on normal service mounting*

operating characteristics of British reclosers and fuses having slow melting characteristics. It will be realized that the range of fault current over which satisfactory operation can be obtained will depend upon the appropriate selection of the recloser and associated fuse ratings.

A cross-section of the British recloser is shown in Fig. 4. The main contacts are normally closed, contact pressure being maintained by an operating spring. When fault current flows through the solenoid operating coil, a link mechanism is carried over dead centre, permitting the main contacts to open with a snap action. An oil dashpot is provided which offers no restraint to the solenoid during the two instantaneous-trip operations, but restrains the closing of the recloser to give a selected open-circuit time. A valve at the base of the dashpot is closed automatically after the recloser has carried out two instantaneous-trip operations, and the solenoid then has to move against the time delay of the dashpot. This is followed by a second time-delay trip operation, and the mechanism is arranged so that, when this second operation is completed, the recloser contacts open and are prevented from closing by a lock-out spring.

Reclosers carry out their trip operations as single-phase units, but by providing a mechanical inter-coupling, three units can be installed on a 3-phase circuit; should any one unit run through to lock-out, arrangements exist for tripping and locking out the remaining two reclosers, thus preventing prolonged interruption of one phase only. An external view of a British recloser under normal service conditions is shown in Fig. 5.

Experience has indicated that reclosers in service satisfactorily perform the function for which they have been designed.

Microwave Surface Texture

A DIGEST OF A RADIO SECTION PAPER (No. 1756) ENTITLED "A SURFACE-TEXTURE COMPARATOR FOR MICROWAVE STRUCTURES," BY A. F. HARVEY, D.PHIL., B.SC.(ENG.), MEMBER. THE FULL PAPER WAS PUBLISHED IN MARCH, 1955, IN PART B OF THE PROCEEDINGS.

RADIO-FREQUENCY CURRENTS in microwave structures flow only near the surface in a thin skin, which, for example, in copper at 30 Mc/s is only 16 microin thick. Thus to avoid undue attenuation it is modern practice in this field to specify limits for the surface roughness or texture, and manufacturers and others concerned must thus have means for estimating this.

Instruments of the stylus type which measure directly the contour of the surface are expensive, and a simple scale for visual and tactile comparison, which can be produced economically by electro-deposition, has therefore been developed. This contains patches of known surface texture based respectively on machining operations giving no tool texture, those using sharp-pointed tools, and those using broad-faced tools.

The range of processes and surface finishes in microinches are those appropriate to microwave manufacturing purposes and are: lap 2, grind 4, 8, 16, 32 and 63; turn 8, 16, 32 and 63; mill 32 and 63. The overall accuracy including errors of comparison is within one scale step, which is considered adequate.

Electroforming

A DIGEST OF A RADIO SECTION PAPER (No. 1757) ENTITLED "THE ELECTROFORMING OF COMPONENTS AND INSTRUMENTS FOR MILLIMETRE WAVELENGTHS," BY A. F. HARVEY, D.PHIL., B.SC.(ENG.), MEMBER. THE FULL PAPER WAS PUBLISHED IN MARCH, 1955, IN PART B OF THE PROCEEDINGS.

COMPONENTS AND INSTRUMENTS for millimetre wavelengths must be manufactured so that the important parts, which are nearly always internal, are accurate in dimensions and have smooth surfaces. Many methods of manufacture have been investigated, and a successful one is electroforming, in which a former, made to the shape of the internal volume required, is electroplated to a thickness sufficient to provide adequate mechanical strength.

A satisfactory electroforming process must give deposits up to $\frac{3}{8}$in thick which are free from internal flaws, possess good throwing power for complicated shapes with sharp corners and have an adequate rate of deposition. A special copper-cyanide bath combined with periodically reversed plating has been found an improvement over the older methods, and a variety of metals can be electroformed with it. Such a bath gives deposition rates of up to 0·006 in/h, the Vickers hardness number of the deposit lying between 120 and 240. Best results are obtained with an operating temperature of 185°F, current densities about 80 amp/ft^2, and alternate cathodic and anodic periods of, say, 60 and 20 sec respectively. Good results, but with lower rates of deposition, can be obtained with operating temperatures down to 120°F. The deposits obtained are smooth and uniform, but all corners on the former must be given a minimum radius to avoid junction cracks. The formers used fall into two classes, namely permanent and disposable. Permanent formers are made of materials such as stainless steel, and since they give very accurate results, are more suited to the manufacture of instruments. Measurements have shown not only that the electroformed piece is free from internal distorting stresses, but that the dimensions and surface finish of the former are reproduced to a high degree of accuracy. There are preferred shapes for these formers, and the use of a machine for extracting them from the electroformed item is desirable. These permanent formers can also be used in multiple assemblies by the use of jigs.

Disposable formers are made of materials such as plastic which can be produced economically and removed easily. They thus lend themselves to the electroforming in quantity of complicated shapes. Such formers are given an initial conducting coat of silver, and the temperature of the plating bath must not exceed 120°F if distortion is to be avoided. Inserts of various shapes can be electroformed in position to give improved mechanical strength or to provide coupling apertures.

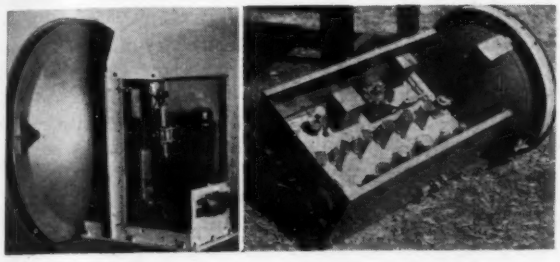
Electroforming has enabled both the mechanical and electrical design of waveguide components to be improved. Items such as directional couplers, accurate wavemeters, and precision waveguide have been used for operation at wavelengths as short as 1 mm. Since semi-optical techniques are then practicable, electroforming has enabled waveguides to be constructed and used over the whole range of wavelengths for which they are suitable.

Microwave Propagation

A DIGEST OF A RADIO SECTION PAPER (No. 1780) ENTITLED "AN EXPERIMENTAL STUDY OF THE PROPAGATION OF MICROWAVES OF 10-CM WAVELENGTH OVER A SHORT NON-OPTICAL SEA PATH," BY E. F. STACK-FORSYTH, B.SC., PH.D., ASSOCIATE MEMBER. THE FULL PAPER WAS PUBLISHED IN MARCH, 1955, IN PART B OF THE PROCEEDINGS.

A SERIES OF MEASUREMENTS of the field strength of microwaves over a path 21·1 miles long was conducted off the coast of Natal during the winter months, April–August, 1953. The path was entirely over the sea, and was 1·14 times the optical horizon. The purpose of the

investigation was to study the effect upon signal strength of variations in the structure of the refractive-index profile of the atmosphere in the first few hundred feet above sea level.



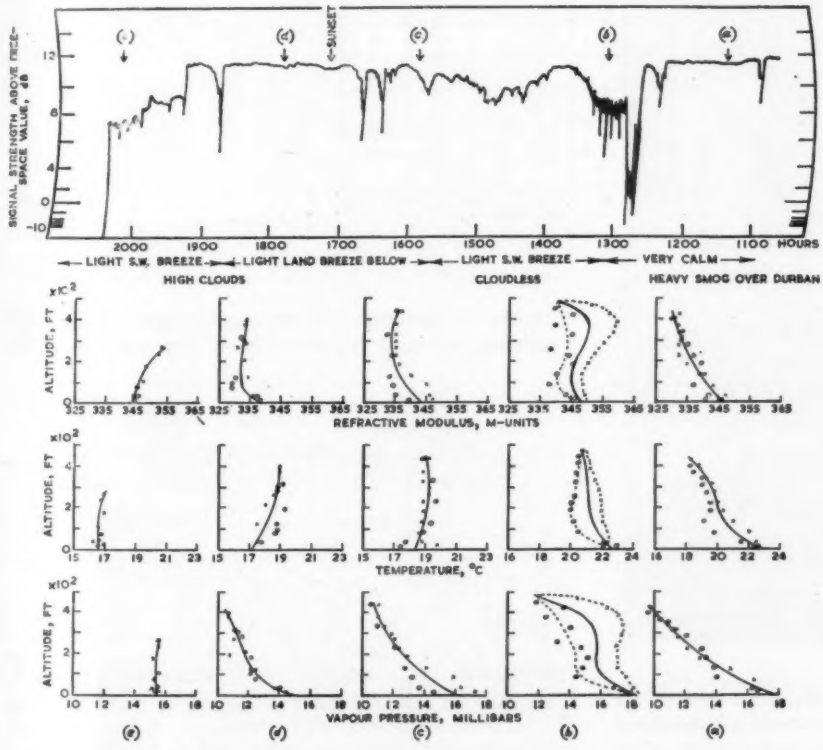
(a) (b)

1 (a) *Transmitter* (b) *Receiver*

The transmitter was a klystron having a rated power output of 100mW. This was square-wave modulated at 1kc/s, and was operated from a fully regulated power supply. The receiver was a conventional superheterodyne having six stages of i.f. amplification, giving some 90dB of gain, and the rectified output was fed to a recording milliameter. Atmospheric temperature and humidity were measured by means of wet and dry thermistors, which were borne aloft by a balloon in calm weather, and by a kite when a wind was blowing. Photographs of the equipment are shown in Fig. 1.

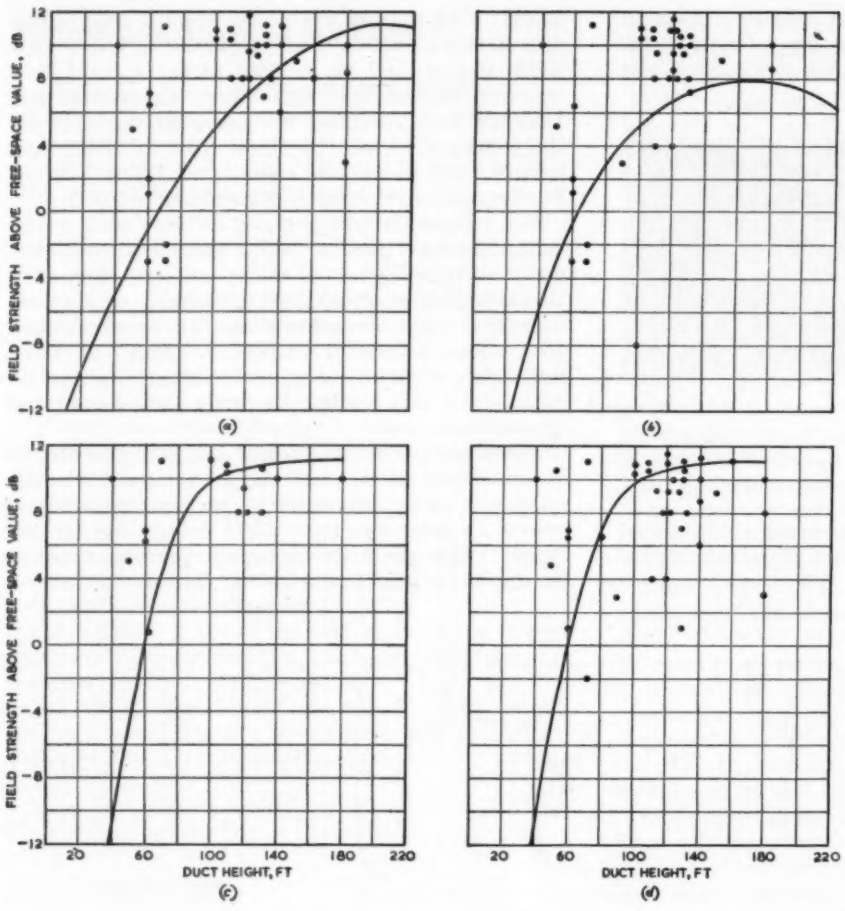
Fig. 2 shows the type of record obtained when a deep surface duct was present. This corresponded to almost complete trapping of the waves, and the effect of a negative gradient of refractive modulus is clearly seen. The fall in signal strength at about 1250 hours coincided with a rapid change in atmospheric conditions, which fact is borne out by the large discrepancy between the atmospheric data obtained on ascent and on descent of the thermistor unit.

Correlation between measured field strengths and the values calculated on the basis of refractive modulus profiles obeying square, fifth-root, and bilinear laws was investigated by plotting field strength against duct height. The results for the various profiles are shown in Fig. 3. The full line shows the calculated values.



2 *Record No. 29; 23rd July, 1953; 1040–2030 hours*

× Ascent. ○ Descent.
(a) 1115–1145 hours.
(b) 1250–1325 hours.
(c) 1540–1610 hours.
(d) 1745–1805 hours.
(e) 2000–2015 hours.



3 *Variation of field strength with duct height*

(*a*) Square-law profile.
(*b*) Fifth-root profile.
(*c*) and (*d*) Bilinear profiles for different values of refractive-index gradient.

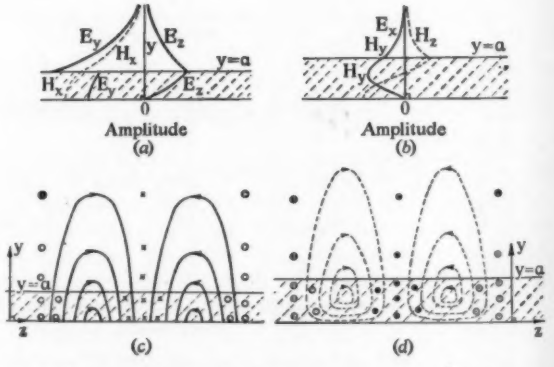
Thirty-nine tests were held, covering a total operating time of 170 hours. The results showed that for 70% of the time the signal was more than 6dB above the free-space value, which suggests that there is a semi-permanent duct along the Natal coast during the winter months.

Launching a Plane Surface Wave

A DIGEST OF A RADIO SECTION PAPER (No. 1783) ENTITLED "THE LAUNCHING OF A PLANE SURFACE WAVE," BY G. J. RICH, M.SC. THE FULL PAPER WAS PUBLISHED IN MARCH, 1955, IN PART B OF THE PROCEEDINGS.

A PLANE SURFACE WAVE is the 2-dimensional case of the surface wave in which it travels onwards unattenuated except by dissipative losses in the guiding system, which in the case considered in the paper consists of a metal sheet coated with a layer of dielectric. Both TE and TM modes are possible, and the form of the field and the magnitudes of its components are illustrated in Fig. 1.

All the components are attenuated exponentially with distance normally upwards from the surface of the



1 *Field components and field lines*

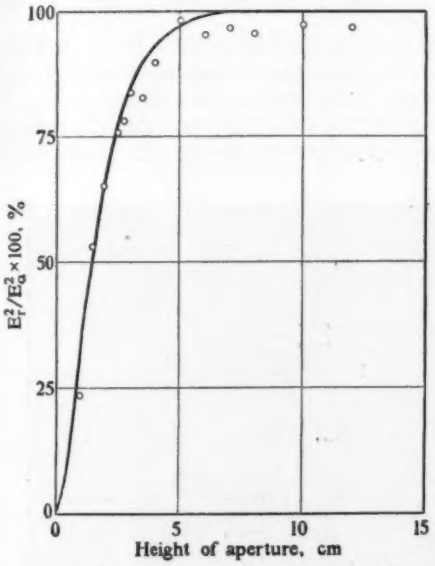
(*a*) Field components; TM_0 mode.
(*b*) Field components; TE_0 mode.
(*c*) Field lines; TM_0 mode.
(*d*) Field lines; TE_0 mode.
———, ○, ● Electric-field lines.
– – – –, ○, × Magnetic-field lines.

dielectric, and their distribution inside the dielectric is described in terms of circular functions.

The surface wave can be excited from an aperture containing such a field. It is assumed that the aperture extends from the surface to a height h above it and that the field is zero outside the aperture and proportional to ϵ^{-kXy} within it, where y is the height above the surface and k and X are parameters of the system. It can be shown that such an initial field distribution will give rise to a surface wave travelling to infinity. Not all the power in the aperture field is transformed into a surface wave field, and it is convenient to define the launching efficiency of the aperture as the ratio of the power in the surface wave field a long way from the aperture to the total power passing through the aperture. It is shown that the launching efficiency, η, is given by

$$\eta = 1 - \epsilon^{-2kXh}$$

Fig. 2 shows the results of an experimental test of this

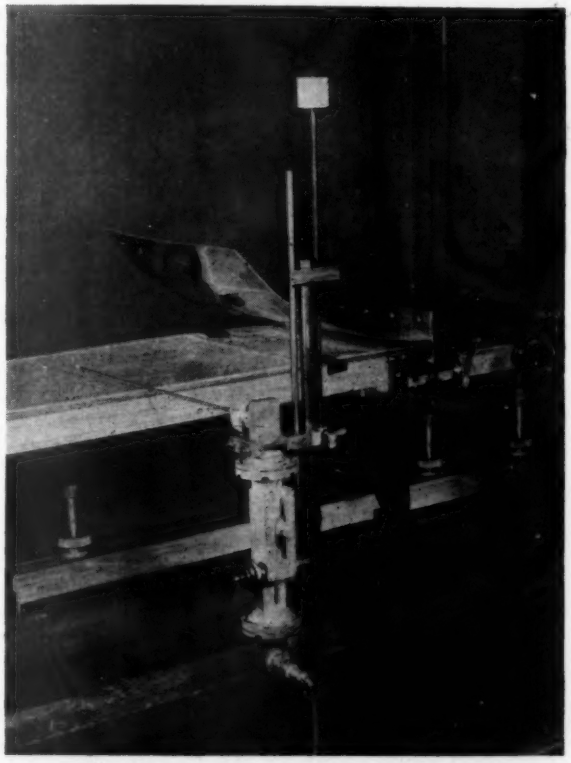


2 *Ratio of squares of electric fields within the aperture and at a distance r = 66 cm beyond it*

$X = 0{\cdot}21$.
$\lambda = 3{\cdot}15$cm.
$k = 2$.
——— Theoretical curve.
○ Experimental points.

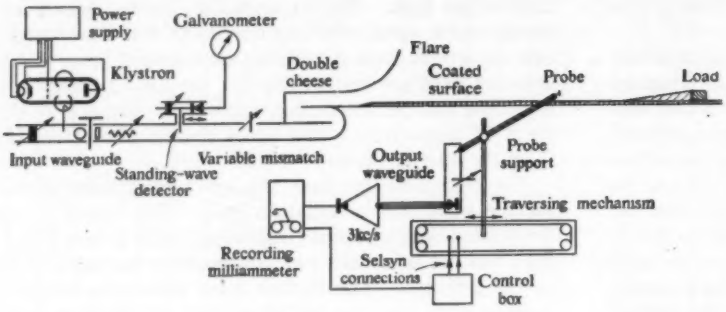
theory. The full line shows the theoretical value of the ratio of the squares of the fields within and at a distance 66cm beyond the aperture. This quantity is equal to the square of the launching efficiency. The guiding surface in this case consists of a film of polystyrene $\frac{1}{10}$in thick on a brass base, and the wavelength is 3·15cm. Under these conditions launching efficiencies of nearly 100% are theoretically possible from an aperture only a few centimetres high. The experimental points shown are in reasonable agreement with the theory, and it is thought that deviations from a perfectly exponential form in the aperture field are responsible for the discrepancies. It is shown that the correction due to the distance of the point of measurement not being removed infinitely far from the aperture is quite small.

The field launched from the aperture consists of the surface wave plus a radiation field. The former is not attenuated with distance (neglecting losses in the dielectric), but the latter falls away inversely as the square root of the distance. The surface wave thus soon becomes predominant over the radiation field at points near to the surface. It was found to be easy to get some of the incident energy into a surface wave—almost any type of launcher will do this, even if the field within it does not approximate at all closely to the ideal exponential form—but efficient launching is attained only with great difficulty. A launcher designed on an empirical basis is shown in Fig. 3, together with the probe used to explore



3 *Experimental launcher and test probe*

the field. The efficiency of this launcher was about 50%. This was deemed to be sufficient for the experiment described above; a "black" screen was set up vertically some 75cm from the launcher so that its lower edge was



4 *Schematic of the apparatus*

parallel to the surface, the space below forming the aperture of the theory. For small distances above the surface this contains a pure exponential field uncontaminated by the radiation field from the launcher. By this method the theory was tested.

Fig. 4 is a schematic of the apparatus. A small dipole probe is used to explore the field and an automatic recording system is used to gather the data. The load consists simply of a number of wedges of resistive card held in a block of wood and with their planes parallel to the electric vector. The flare of the launcher is preceded by a double-cheese aerial, which forms the necessary line source.

This machine was run at above normal voltage following these tests, but subsequently failed to withstand the standard 1-min high-voltage insulation test at 28·6kV between phases and to earth. Upon investigation it was found that, although the mechanical damage to the winding and its bracing was slight, the insulation strength of 19 half-coils out of 120 had been reduced by the short-circuit tests.

In order to compare the performance of two different forms of end-winding support, they were incorporated at opposite ends of the replica stator shown in Fig. 1. This consisted of two full-sized overhangs comprising properly insulated conductors having only a very short

Short-Circuit Forces in Turbo-Alternators

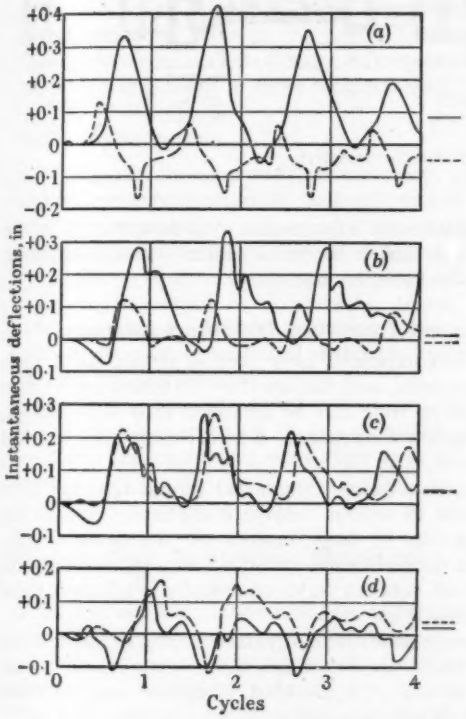
A DIGEST OF A SUPPLY SECTION PAPER (No. 1683) ENTITLED "SHORT-CIRCUIT FORCES ON TURBO-ALTERNATOR END-WINDINGS," BY J. B. YOUNG, B.SC., AND D. H. TOMPSETT, B.SC.(ENG.), ASSOCIATE MEMBERS. THE FULL PAPER WAS PUBLISHED SEPARATELY IN JULY, 1954, AND IT WAS REPUBLISHED IN APRIL, 1955, IN PART A OF THE PROCEEDINGS.

IN A TURBO-ALTERNATOR the end connections joining two coil sides comprise suitably shaped and supported conductors projecting from the stator slots. A magnetic field of somewhat complex distribution is set up throughout the overhang whenever currents flow in the windings; mechanical forces varying in magnitude and direction during the cycle are experienced at each point on the conductors. These forces attain extremely high instantaneous values during the first instants following a short-circuit, and they must be restrained by the supporting structure and binding. Both forces and constraints must be reproduced in any apparatus designed to assess the performance of a particular form of end-winding support.

The paper reports the consequences of some acceptance-test short-circuits, including one from rated voltage, carried out on a 60MW 13·8kV 3600-r.p.m. alternator.

1 *The replica stator subsequent to a test with currents equivalent to a full-voltage short-circuit on the alternator*

slot-embedded length as shown. Currents equal to those flowing under short-circuit conditions were passed through the windings and the resulting conductor movements, particularly those in the vicinity of the coil knuckles, were recorded oscillographically and by means of high-speed cameras. In Fig. 2 is shown the form of



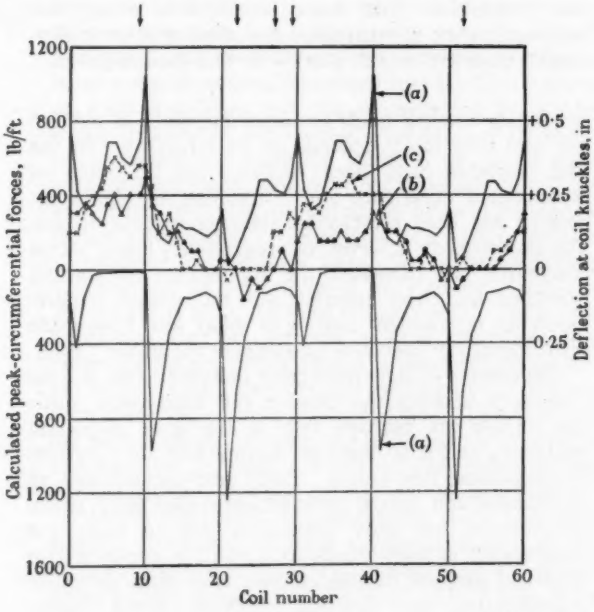
2 *Instantaneous deflections measured at points between the knuckles and the core at each end of four coils during 3-phase short-circuit*

Coil numbers: (*a*) 41 (11); (*b*) 51 (21); (*c*) 20 (50); (*d*) 1 (31).
Initial 3-phase short-circuit current: 47kA r.m.s.
Final positions indicated by lines at right.
———— Original bracing.
– – – – Redesigned bracing.

the oscillations measured during one test, and Fig. 3 shows the correlation of the calculated peak forces with the permanent deformations recorded after the tests on both the alternator and the replica stator.

A series of investigations was made to establish the validity of carrying out such tests without representing the effect of the alternator rotor. The conclusions reached are that, with respect to the circumferentially directed forces which produce the damage to the coil insulation, an equal-current test on such a replica winding is more severe than one carried out on the alternator. The degree of difference in this severity depends mainly upon the properties of the rotor retaining-ring and is greater if this is of magnetic rather than non-magnetic material.

A study of the different types of fault which may occur in practice has shown that the effect of an insulation breakdown or a flashover between conductors is to produce considerably lower forces than either the theoretically most severe cases or the bolted short-circuit



3 *Results of short-circuit tests*

(*a–a*) Calculated envelope of peak forces at coil knuckles for a particular short-circuit from rated voltage.
Permanent circumferential deflections measured at coil knuckles on:
(*b*) Alternator.
(*c*) Replica stator similarly braced to alternator.
↓ Location in alternator of coils found to have reduced insulation strength following short-circuit test.

usually required for acceptance tests. This reduction results from the decrease in asymmetry of the currents and also from the arc resistance.

In early power installations the occurrence of a terminal short-circuit was an operational contingency which might be expected to occur during the life of a generator; present-day power-station layouts make negligibly small the likelihood of such a fault. Since subjecting an alternator to a full-voltage short-circuit results in some deterioration of insulation, the authors recommend that consideration should be given to the specification of a less onerous test by which to prove the general mechanical soundness of the winding supports while still obtaining the required measure of the alternator characteristics.

Measuring Turbine-Rotor Movements

A DIGEST OF A SUPPLY SECTION PAPER (No. 1680) ENTITLED "THE ELECTRICAL MEASUREMENT OF STEAM-TURBINE ROTOR MOVEMENTS, WITH SPECIAL REFERENCE TO THE OPERATION AND DESIGN OF MODERN POWER PLANT," BY J. L. ASHWORTH, A.M.I.MECH.E., ASSOCIATE MEMBER, J. S. HALL, B.SC.TECH., A.M.I.MECH.E., AND A. H. GRAY, M.SC., MEMBER. THE FULL PAPER WAS PUBLISHED SEPARATELY IN SEPTEMBER, 1954, AND IT WAS REPUBLISHED IN APRIL, 1955, IN PART A OF THE PROCEEDINGS.

THE STEAM TURBINE holds an important place in modern life, and thus much depends on its reliability. In the past, turbines have been operated on the basis of accumulated experience and a tradition of high competence has been established amongst turbine drivers. The employment, however, of progressively higher steam conditions has increased the significance of starting problems, and these, together with the modern requirements for intermittent loading of many sets, have made instrumentation necessary to augment the driver's skill.

The control of transverse rotor deflection and of axial clearances between the moving and fixed parts inside the turbine are perhaps two of the most important problems, and it is therefore natural that the solutions for these were first sought. Early instruments based on mechanical and optical principles provided much useful information, but their limitations due to wear and inaccuracies at high speeds soon made it apparent that electrical methods of measurement were more desirable. Furthermore, the electrical methods could readily incorporate a permanent record, which has since proved of great value.

The original turbovisory equipment consisted of two fundamental measuring devices.

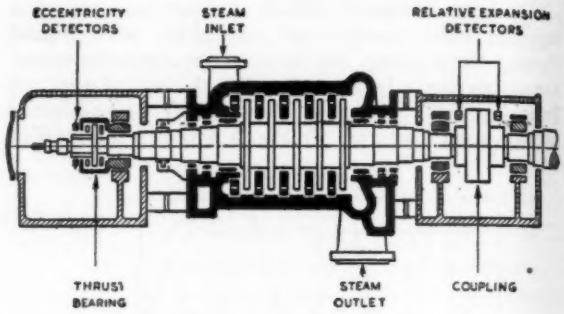
Differential Axial Expansion and Shaft Deflection

Two detector magnets anchored to the turbine stator are arranged with their pole faces equidistant on either side of a suitable flange on the rotor system. A bridge-connected network enables both indicating instruments and recorders to measure any relative movement between the rotor and stator system.

A second pair of detector magnets situated in a suitable bearing pedestal are arranged with their pole faces equidistant on either side of the rotor shaft. Again a bridge-connected network followed by an amplifier enables indicating instruments and recorders to measure the eccentricity of the shaft at all speeds.

When it is realized that a deflection of approximately 0·004in of the centre of the mass of the rotor produces a centrifugal force at 3 000r.p.m. which is equal to the weight of the rotor, the need for high sensitivity becomes apparent.

The diagram illustrates the normal disposition of the detector magnets in a turbine cylinder. In practice it has been found desirable to install the gear on both high- and intermediate-pressure cylinders, but so far no occasion has arisen to make similar measurements on low-pressure cylinders necessary.



Location of detector magnets

Reliability and Accuracy of Turbovisory Equipment

Some 60 equipments have been in service for periods up to nine years, and the few troubles which have arisen from time to time can be classified into four groups, namely system disturbance, detector magnets, electrical leakage and valve life.

System disturbance. Occasional erratic readings have been traced to serious voltage disturbances due to the direct starting of large motors on the same supply. Improved stabilization of the circuits and careful selection of supplies have completely eradicated these sporadic readings.

Detector magnets. The original covering of the detector magnets has in some instances shown signs of oil penetration. The use of a moulded Neoprene case has now obviated all such troubles.

Electrical leakage. The presence of live steam round the amplifier has on occasions led to errors. The high-impedance circuits in this equipment have accordingly been changed and all such troubles now removed.

Valve life. Originally it was felt that valves should be replaced at fixed periods. Subsequent experience, together with a carefully prepared set of tests, has changed this view-point and valves are now replaced only at infrequent intervals depending upon the results established by these routine tests.

Operation of Turbovisory Equipment in Power Stations

Numerous examples in the paper illustrate that the turbovisory equipment has enabled the operation staff to prevent permanent damage to rotor shafts during the run-up period. An interesting example is also given which demonstrates the value of the records. Comparison of the records taken over some six months of operation indicated a small but continuous increase in the eccentricity reading. Subsequent examination of the rotor proved that a small permanent bend had occurred, and the appropriate remedy was applied before serious trouble could arise.

While there is still much to be considered in connection with the operation of these turbines, the measurements given by the turbovisory gear have established the importance of steam/metal differential temperatures and have enabled quick starts to be made quite successfully when the temperature is carefully controlled.

So far the uses of this equipment have been discussed with relation to operation; equally important contributions have been made to the design knowledge of turbines, and many aspects of design have been and are being examined as a result of these measurements.

Future Developments

While the fundamental measurements already discussed, namely eccentricity and differential expansion, are still regarded as very important, experience has suggested useful additional measurements. The modern turbovisory equipment is now capable of giving the following information: eccentricity, speed, differential axial expansion, overall expansion, generator power output, sundry steam/metal temperatures and, where desired, bearing vibration.

While it is usual to accommodate this equipment on the turbine gauge panel, it is sometimes preferred to associate the equipment with other gear on a separate cubicle.

Balancing Rotating Machines

A DIGEST OF A STUDENTS' PAPER ENTITLED "MODERN ELECTRICAL METHODS OF BALANCING ROTATING MACHINES," BY E. P. FOWLER, M.A., GRADUATE. THE PAPER WAS AWARDED A STUDENTS' PREMIUM BY THE COUNCIL, AND A LONG ABSTRACT OF IT WAS PUBLISHED IN THE STUDENTS' QUARTERLY JOURNAL, DECEMBER, 1954.

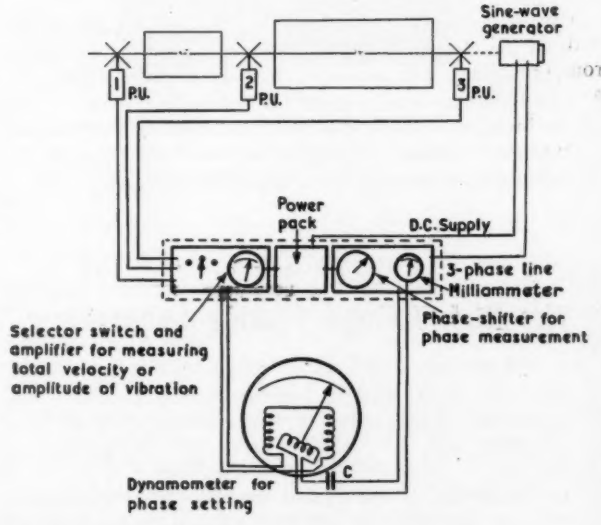
THE ROTORS of large machinery have for a long time been balanced by trial and error. With modern methods there is still trial but much less error, and the result is probably a smoother-running machine. The unbalance of a simple stiff rotor will be static, dynamic or a combination of the two. Static unbalance is essentially due to the centre of gravity lying off the rotation axis; in dynamic unbalance the centre of gravity is on the axis, but the rotor centre line is skew to the axis of rotation.

It is accepted that any rigid rotating mass can be balanced by the addition of balance weights set in the correct angular position in two planes at right angles to the axis of rotation. These weights improve the balance by introducing at the bearing supports centrifugal forces equal and opposite to those produced by the unbalance. There are several compromises in practice; for instance, it is easier to measure some result of the out-of-balance force, such as vibration of the pedestal, rather than the force itself, and it is quite impossible to have the balancing plane where the measurement of vibration is made.

The vibration amplitude is measured with seismic electric pick-ups, and its phase (relative to an arbitrary reference on the shaft) is determined with the aid of a reference generator on the end of the shaft. With this information, three trial runs are necessary and sufficient to balance the rotor, with a fourth run as a check that the balance is correct.

Unfortunately, except in a balancing machine, no high-speed rotor behaves as a rigid rotating mass, and a different approach may be necessary. As a long flexible machine is run up to speed, the unbalancing vibration reaches a peak at the first critical speed. This is known as static unbalance and can be corrected by a single weight or a weight at each end. Similarly, at the second critical speed the vibration reaches, or would reach, another peak characterized by the pedestals vibrating in anti-phase; this can be corrected by weights on two planes in opposition. Unfortunately, if a large correction is necessary for the static unbalance, quite large third-order unbalance may occur at the running speed, even if it is remote from the third critical speed. Third-order unbalance can be corrected only if there are three balancing planes. Sometimes it is prevented by machining away metal along the slot wedges of the rotor to correct for the initial static unbalance. In addition to the main body of the rotor, the shaft ends, with coupling and slip-rings on them, are relatively more flexible than the body of the rotor and require individual attention.

Portable electronic equipment has been developed recently for balancing large turbo-alternators, to give accurate measure of the vibration amplitude and relative phase on any pedestal of a machine. The Figure shows the general arrangement. The pick-ups are of the seismic type and give an output proportional to the vibration velocity. The output is integrated electrically,



Schematic of the equipment
P.U. Pick-up.

and on the most sensitive range of the instrument the full-scale deflection occurs for 0·001 in peak-to-peak vibration. Phase angle is determined by balancing the pick-up output against a reference signal obtained from a reference generator on the shaft. A null reading is obtained on the dynamometer without the necessity of touching the reference generator.

The procedure for using portable balancing equipment in factory test is, as near as practicable, that outlined earlier. On site, however, the problem is not so much to balance a single rotor as to produce a smooth-running machine. Many faults are attributed to out-of-balance and can often be rectified by deliberately putting unbalance into a previously balanced rotor. For this reason, each time a new machine is balanced the problem must be approached with an open mind, both as to what is required and what can be done.

Examples of machines that can with advantage be balanced in their own bearings vary from the smallest fan to the largest turbo-alternator. In each case the degree of balance to be sought will need to be agreed upon. Obviously a great deal depends on the situation, but for a permanently-installed large machine a peak-to-peak amplitude of vibration of 0·001 in at 3 000 r.p.m. may be considered reasonable. This is equivalent to an r.m.s. vibration velocity of 0·1 in/sec, which should be acceptable over the speed range 600–12 000 r.p.m.

There appears to be little technical difficulty in extending the method outlined to speeds of 20 000 r.p.m., but at low speeds the conventional seismic pick-up becomes unwieldy. The alternative is to use an accelerometer, which need have no low-frequency limit, followed by integrating circuits and sensitive amplifiers to compensate for the small signals. Such an equipment can be made for speeds as low as 100 r.p.m. and with a sensitivity comparable to that of the conventional balancing equipment.

Most of the problems met to date have been concerned with the electrical rotors of turbo-alternators. Turbine roughness is not generally ascribed to out-of-balance, and little provision is made for balancing on site. With the building of multi-span machines with solid couplings, however, greater emphasis will have to be laid on balancing turbines in their own pedestals.

The High-Voltage Testing Laboratory

A DIGEST OF A STUDENTS' PAPER WITH THE ABOVE TITLE BY R. E. JAMES, B.SC.(ENG.), GRADUATE. THE PAPER WAS AWARDED A STUDENTS' PREMIUM BY THE COUNCIL.

ONE FEATURE of the recent increases in transmission voltages has been the attention focused on the facilities available for testing at the new insulation levels. At the present time impulse tests of up to 1 350 kV (peak) are being specified, while steady-state tests are approaching 600 kV (r.m.s.).

The paper indicates some factors influencing the design of the equipment required for high-voltage testing under transient and power frequency conditions.

The design and layout of the testing plant in a high-voltage laboratory is governed largely by the electrical and physical characteristics of the apparatus to be tested and the exact nature of the tests to be performed. To assist in the economic utilization of the space available in a laboratory, the electrostatic design of individual equipments should, if possible, be correlated with each other and with the building structure. Under certain circumstances reductions in clearances may contribute to the onset of corona; methods of controlling this troublesome phenomenon are mentioned.

Among the problems arising during testing is that associated with the safety of personnel, which may be acute where the test and production areas are adjacent.

In practice, the impulse and power-frequency test equipments are usually accommodated in the same area, but in the paper they are considered separately in order to simplify the presentation.

Impulse Testing Equipment

The simplest representation of a circuit for producing impulses of the desired form consists of a charged capacitor which may be discharged through a combination of series and shunt resistors and the resultant voltage applied to the load.

Such an arrangement cannot be calculated accurately, owing to the losses, stray effects and inductances, thus making the determination of the correct series (wavefront) and shunt (wavetail) resistors to give the standard 1/50-microsec wave—B.S. 923: 1940—a matter of varying complexity requiring theoretical and experimental analyses.

For the higher peak voltages the limitation in the charging voltages at present available precludes the use of a single capacitor, and resort is invariably made to a multi-capacitor circuit of the form originated by Marx. This not only reduces the charging voltage required, but also adds to the versatility of the impulse generator. Various modifications of the Marx circuit have been introduced and methods developed for incorporating the waveform resistors into the structure of the generator.

The output from the impulse generator may be recorded in magnitude and shape on a low-voltage high-speed single-sweep oscillograph by employment of a high-voltage potential divider, calibration being normally achieved by use of a standard sphere-gap. To ensure satisfactory recording a method of synchronizing the oscillograph time-base and the generator tripping circuits must be employed either by using a delay cable or, better, by separate low-voltage triggering pulses.

Although impulse testing is becoming of greater importance and the technique more reliable—particularly with respect to fault detection—steady-state acceptance tests are still invariably required.

Power-Frequency Testing Equipment

In many respects the production and measurement of high voltages at power frequencies are simpler than those involving impulses of comparable value. Nevertheless, the longer duration of tests may contribute to the creation of more complex insulation problems. The high-voltage transformer itself presents, amongst other features, a formidable problem in insulation design; coils in which hundreds of kilovolts are induced must be accommodated in close proximity to the core and the tank, and connection must be made between the coil output lead and the external circuits; the design of the coil and the bushing require careful investigation of the electrostatic field present under both power-frequency and impulse conditions. The fully shielded concentric-layer type of winding with internal cross-overs is especially suitable for this application, for it is amenable to the grading of insulation and has an excellent response to surge voltages.

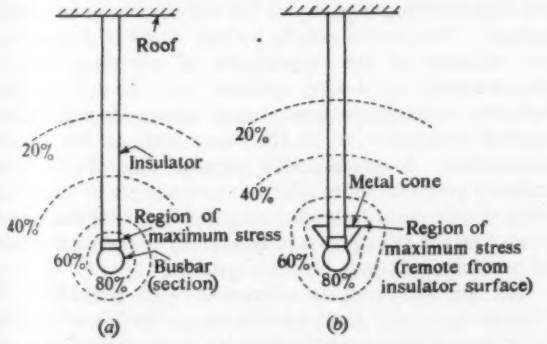
Single-unit testing transformers have been designed for operation at 1 000kV (r.m.s.), but the more usual arrangement is to connect two or three units in cascade, thereby reducing the individual insulation levels for a given overall output, although increasing the space occupied.

The measurement of the high voltage may be effected by a standard sphere-gap, possibly in parallel with a potential divider and associated voltmeter. In many laboratories it is also necessary to install h.v. equipment for measurement of dielectric loss-angle.

A very real problem in the design of layouts is the method of interconnection of equipment at the high voltage, particularly where the building height is a limitation. In this respect the reduction of clearances may sometimes lead to partial breakdown of the air, giving rise to corona.

Corona in the High-Voltage Testing Laboratory

In general, corona has considerable nuisance value in the high-voltage laboratory and various methods must be adopted to prevent dangers of flashover and instability;



1 *Approximate potential distribution around a h.v. busbar before and after the addition of a metal cone*

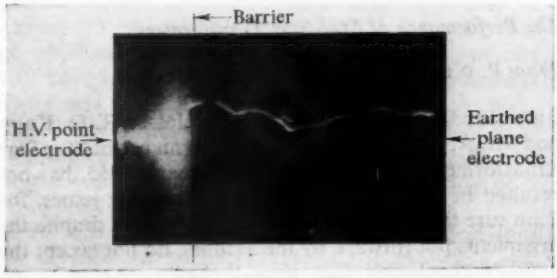
an example of electrostatic screening at earth potential is described in the paper.

On occasions, however, air corona may be encouraged at predetermined positions, in order to relieve excessive electric stresses elsewhere, e.g. along insulator surfaces. This latter application is exemplified by consideration of a h.v. busbar system which, although exhibiting vicious corona at 500kV (r.m.s.), was finally operated satisfactorily at 700kV (r.m.s.); the improvement being achieved by the fitting of thin metal cones at the junction of the suspension insulators and busbars. It may be of interest to note that, during the operation of h.v. systems on which corona is occurring, the power component of current so introduced tends to improve the circuit power-factor and add to stability.

Although the elimination and control of corona has many aspects, according to the particular conditions prevailing, a device that has been used to prevent direct breakdown in air is the little exploited practice of installing large insulating barriers.

Barriers in the High-Voltage Laboratory

The application of such barriers is especially suitable for indoor conditions and at voltages where there is a tendency for corona to exist. It would appear that the considerable reductions in clearances so obtainable makes this expedient an attractive proposition where space considerations are limiting.



2 *Puncture of a paper barrier at power frequency*
Ratio of r.m.s. breakdown voltages with and without barrier = 80 000/45 000. Gap length = 10cm.
The apparent break in the spark is due to the supporting frame.

The method is apparently little practised, probably owing to practical difficulties and insufficient technical data. To this latter end, various published test results for voltages of the order of 500kV and upwards are considered in the paper, together with details of experiments performed at voltages of 100kV (r.m.s.) and below with a point-plane gap and paper barriers. From these data it is concluded that large increases (of the order of 80–100% in a point-plane gap) in breakdown voltages are possible, depending on such factors as the electric-field distribution, the barrier position in the field and the size of the barrier; the manner in which a barrier tends to act as a baffle to corona is illustrated.

CORRESPONDENCE

"Henry per Metre." An Absurdity

From PROFESSOR G. F. NICHOLSON, *Member*

In his letter in the April *Journal* Mr. L. H. A. Carr sums up the three principal characteristics of a natural constant as its dimensions, its numerical value and the unit in which this numerical value is expressed.

The first two of these depend upon the system of units adopted (provided that one arbitrarily decides to associate one's primary units directly with one's fundamental dimensions). The third is subjective. It depends upon the way in which the man using the unit finds it most useful to relate his mental processes to the world about him. It would be unscientific to label his unit as either reasonable or absurd without reference to this relationship. Mr. Carr does refer to it; but, in doing so, he begs the question by assuming a particular definition of inductance, and so, a particular man.

Most media capable of transmitting waves are characterized by two storage parameters, one associated with inertia, and the other with compliance. If anyone finds it convenient to consider free space from the "luminiferous ether" point of view, he may also find it convenient to regard it as endowed with specific electrical inertia and with specific electrical compliance. In this event, suitable definitions of inductance and of capacitance lead quite naturally to the "henry per metre" and the "farad per metre" as the units for these specific quantities in the rationalized M.K.S. system. As has been pointed out on various occasions, it is a pity that tradition prevents us from calling them, in this context, "inductivity" and "capacitivity" respectively.

We are not concerned here with a philosophical discussion of the nature and properties of free space, but, merely, with convenience of thought and of communication. Mr. Carr himself speaks of the permeability of free space.

It is not clear why Mr. Carr's objections to the "farad per metre" are not quite so strong as his objections to the "henry per metre." There is, of course, a great weight of authority behind the name "specific inductive capacity."

Professor Nicholson is Professor of Electrical Engineering at the Royal Naval College, Greenwich.

The Performance of Star-Star Transformers

From P. D'E. STOWELL, B.Sc.(Eng.), *Member*

I am surprised that the article by Professor R. O. Kapp and Mr. A. R. Pearson on "The Performance of Star-Star Transformers" in the *Journal* for January, 1955, has not resulted in your publishing letters in ensuing issues, for I am sure that there are many engineers who, despite the arguments put forward by the authors, do not accept the article's conclusion that three-limbed core-type transformers need be provided with a tertiary winding only in quite exceptional circumstances. Certainly I cannot accept it myself, if I interpret "quite exceptional circumstances" correctly, nor can I accept the basis for this conclusion.

I propose to mention in detail only two of the points about which I disagree with the authors. The first is concerned with voltage rise on unbalanced loads. Professor Kapp and Mr. Pearson point out that with a three-limbed star-star transformer supplying a 4-wire distribution system, the neutral displacement with a 10% out-of-balance current may be of the order of 3%. They imply that this is of little consequence, as indeed it would be if the transformer were supplying a 3-wire system; but when it is supplying a 4-wire system I suggest that a neutral displacement of 3% is most important. This is because there are few systems on which the maximum permissible load is not limited by voltage drop, and on such systems it is not sufficient to control the voltage drop only between lines, but also—indeed in most systems more importantly—between each line and neutral. On 4-wire systems, e.g. at 240/415 volts as in Great Britain, with most of the load connected between line and neutral, it is not easy to balance the load within 10%, and the resulting 3% neutral displacement is no less than half of the permissible voltage variation, which by statute is limited in Great Britain to $\pm$ 6%. If, to supply such systems, transformers without delta windings were used in accordance with the author's conclusion, the load-carrying capacity of the system would be about halved. This would usually be little short of disastrous. As evidence of the importance of avoiding neutral displacement in 4-wire systems, the British supply industry consistently uses 4-core cables in which the neutral conductor is of the same size as the phase conductors. I emphatically suggest that the supply industry could no more afford to save copper by omitting delta windings on transformers supplying 4-wire systems than it could afford to save copper by reducing the size of neutral conductors on such systems.

The second point is concerned with the effect of voltage rise under fault conditions on the life of lamps. Here the authors estimate that, for every second that an earth fault exists on a 4-wire system fed by transformers without delta windings, lamps will be robbed of about

Mr. Stowell is with the Merseyside and North Wales Electricity Board.

10 min of their normal expectation of life. I do not quarrel with this, or with the subsequent statement that the aggregate duration of earth faults cannot affect the life of lamps appreciably. However, I think that is not the whole story. There is, I suggest, a psychological factor as well. Whenever an earth fault occurs on a system, a few of the lamps alight will be sufficiently close to the end of their life to be put out of their misery by the resulting voltage rise. On the other hand, other lamps alight in the same premises will survive the short period of brilliant living. It will be truly remarkable if the consumer does not see this and complain very forcibly that the supply authority is responsible for destroying his lamp, and he may even drag in his television receiver as well. Satisfactory answers would be very hard to find, and in case the authors may think that consumers would not be so unreasonable as to make such complaints, I can assure them that the supply industry has to deal with many grumbles with very much less substance in them than these. I think too that the number of lamps failing on each fault might well be a much greater proportion of those alight at the time than the 1 in 6000 represented by the authors' 10 min reduction in a 1000 h life, since I suspect that lamps, like human beings, become less able to survive abnormal conditions as they grow older.

I believe that it is fortunate that most transformers have for good reasons delta windings on them. Contrary to Professor Kapp and Mr. Pearson, I should therefore think twice about omitting a delta winding where it is not obviously convenient to have one, and their article leads me to the conclusion that I should definitely not do without a delta winding on any star-star transformer feeding a 4-wire system, except in the unusual circumstances when the system feeds an almost entirely 3-phase (and therefore inherently balanced) load; or on any star-star transformer feeding a 3-wire system, except when the neutrals of both windings and the supply system are earthed, or when one neutral only is to be earthed through a comparatively high impedance. This seems to be an outlook almost opposite to that of the authors.

Reply from PROFESSOR R. O. KAPP, B.Sc., *Member*, and A. R. PEARSON, B.Sc., *Member*

We quite agree with Mr. Stowell that a delta winding would be necessary if star-star transformers served a 4-wire distribution system, and we welcome the cogent arguments with which he supports that view. But when does one have to employ star-star transformers at all on such systems? Surely the occasions must be rare when a particular phase displacement of the low-voltage system or any other consideration needs to govern the choice of transformer connection. We think that the distribution engineer is nearly always free to install either star-star transformers with a delta-connected tertiary winding or delta-star transformers with no tertiary winding. On such occasions we should not hesitate to choose delta-star transformers, and we believe that this is mostly done by distribution engineers.

Under what circumstances are star-star transformers generally employed? For low-voltage supplies we believe their use is restricted mainly to closely interconnected systems such as occur in factories or on power-station auxiliary circuits where, in order to provide cophasal supplies from alternative sources, it may be necessary to install some star-star transformers. For such applications the phase/neutral loads are usually small compared with the 3-phase loads. Star-star transformers are also frequently employed on high-voltage interconnectors where the power flow may be in either direction, but since then the high- and low-voltage neutrals will both be earthed, the utility of a tertiary delta winding is debatable.

If we have underestimated the number of occasions when circumstances make it essential to provide a star connection on both the primary and secondary sides of low-voltage distribution transformers, the need for star-star transformers with a tertiary winding may, of course, be less exceptional than we thought.

Technical Education and Training in Germany

From K. R. STURLEY, PH.D., B.Sc., *Member*

I am grateful to Mr. Welbourn for his amplification in the May *Journal* of my survey of technical training in Germany. We do need to pay more attention to the training of craftsmen, particularly those employed in the smaller firms. His analysis of what is achieved with graduate engineers by our own methods and the German method of training is in my opinion correct. My original report, on which the survey in the *Journal* was based, states: "The impression gained during the visit was that the post-graduate work was more of a design than of a research nature."

Contrary to Mr. Welbourn I found no desire on the part of the *Technische Hochschulen* authorities to join up with the universities, and many claimed advantages for isolation of the applied sciences. Since there is a vocal body of opinion in this country advocating something similar to the *Technische Hochschule*, I felt it important to stress that I had not been able to find any outstanding advantages for it over our own method of an engineering faculty as a part of university life.

Dr. William Gilbert

From G. F. GAINSBOROUGH, PH.D., *Associate Member*

The conflict between the modern authorities that Mr. MacKechnie Jarvis quotes in the March *Journal* on the subject of the date of Dr. Gilbert's birth represents, I suggest, not controversy but confusion. Apart from S. P. Thompson, who changed his mind in 1903 after his discovery of new evidence, the authors mentioned appear to have considered only the published accounts of Gilbert's life. The matter can be advanced only by studying the original evidence, the main items at present known being those mentioned in my previous letter.

There is no confusion in this matter between Dr. Gilbert and William Gilbert the younger. The evidence for Dr. Gilbert's birth in 1544 refers expressly either to Gilbert the exponent of magnetism or to Dr. Gilbert the physician. The younger William was a bachelor, not a doctor, of his faculty and a parson. The roll of the Royal College of Physicians shows only the one Dr. Gilbert to whom the evidence could apply.

The statements that appear in various books that Gilbert went to Oxford as well as to Cambridge are all derived from one source, a remark by Anthony à Wood in his *Athenae Oxonienses*, published about 150 years after the supposed event. Mottelay's reference to two authorities is misleading because one merely quotes from the other. I do not think anyone has succeeded in finding the faintest hint of confirmation. Gilbert's memorial stone erected by his brothers refers to his being at Cambridge but does not mention Oxford. Nor does Gilbert's will mention the alleged bequest of a portrait to Oxford. Mottelay, whom Mr. MacKechnie Jarvis cites on this matter, is not a reliable source of information on Gilbert's life. He was writing in America in the 19th century, a long way from the original data, and he seems to have had to rely solely on previous publications. He not only repeated most of the errors and unauthenticated statements already in print, but introduced a few new ones of his own.

Thompson's inference that Gilbert died of the plague was drawn from a passage in a letter that would be consistent with any other cause of death. His subsequent argument that, since Gilbert is believed to be buried in Colchester, he probably died there, is gravely weakened by the fact that Gilbert left instructions that he should be buried in Colchester. Thompson's speculations may well have arrived at correct conclusions, but nobody knows. With the passage of time, however, these, like other ill-founded stories about Gilbert, are now quoted and requoted as if they were established fact.

Few facts are known about Gilbert's life, and writers at the turn of the century, like Mottelay and Thompson, not only filled in some of the gaps by speculation, but were also sometimes misled by their enthusiasm into accepting evidence uncritically in a way they would have deplored in scientific work. The following example might have tickled the fancy of another William Gilbert, whose activities were flourishing at the time not far from Savoy Place.

In 1903 Thompson stimulated the observance of the 300th anniversary of Gilbert's death, and led the President of The Institution and a party of members to Colchester, where, in company with the local dignitaries, they paid their solemn respects at a house called Tymperleys that was Gilbert's principal residence and the place of his birth. Or so they thought. Unfortunately it was the wrong Tymperleys; but it seems that the success of the occasion was unimpaired by this defect in the proceedings.

[This correspondence is now closed.—*Editor*.]

OBITUARY

ALEXANDER ANDERSON

Alexander Anderson, O.B.E., J.P., who died on the 25th January, 1955, was born in 1872. He studied mathematics, engineering and mining at the Royal Technical College, Glasgow, and was apprenticed for some years to a colliery undertaking. In 1896 he joined the Glasgow firm of Mavor and Coulson as a design draughtsman engaged on electric generators, motors, switchgear and coal cutters. It was during this period that he decided to devote his life to the manufacture of equipment that would improve working conditions underground, and in 1899 he formed with Thomas Boyes and Daniel Burns the firm of Anderson, Boyes and Co. for the purpose of manufacturing and installing electrical mining equipment.

The first machine that the company made was a disc-type coal-cutter, fitted with a series-wound d.c. motor and open gearing of cast steel. This was followed in 1900 by a skid-disc cutter with a shunt-wound d.c. motor and protected gears. Both Mr. Anderson and Mr. Burns often followed night shifts at the coal-face to gain first-hand knowledge of the behaviour of their equipment under actual conditions of operation. The works of the firm were set up at Flemington, where they still are to-day, and they have turned out a varied range of mining equipment. In the two world wars they carried out much general engineering work for the Government. Mr. Anderson was managing director of the company from 1904 until his death. He was a pioneer in the design and manufacture of flameproof apparatus for mines, and an excellent test plant for research on such equipment was installed at Flemington.

In his earlier days Mr. Anderson personally supervised many electrical power installations. He was a founder member of the Association of Mining Electrical and

Mechanical Engineers, in which he always remained very interested. He was fully aware of the need for better safety measures in coalmines, for better equipment, and for better training of miners. He was President of the West of Scotland Branch of the A.M.E.M.E. from 1909 to 1911, National President in 1913–14 and Treasurer from 1918 to 1929.

He gave much time to public affairs; he was a Magistrate for the Burghs of Wishaw and Motherwell from 1917 to 1923, and in 1928 he became Provost, a position which he filled with dignity and efficiency for three years. For a long time he was also a Justice of the Peace for Lanarkshire. He was made an O.B.E. in 1953 for his services to the public.

Alexander Anderson was a keen member of the Church of Scotland and supported it generously. He is survived by his widow, two sons and two daughters.

He joined The Institution as a Member in 1910. In addition to his long association with The Institution of Mining Engineers, he was a member of the Mining Institute of Scotland. A. B. M.

ERNEST EDWARD SHARP

Ernest Edward Sharp, who died at his home in Cape Town on the 13th December, 1954, was born on the 1st January, 1879. In 1892 he joined the London office of Mather and Platt, transferring in 1896 to the Chloride Electrical Storage Co. Meanwhile he was studying engineering at the Chelsea Polytechnic. He was appointed in 1900 to Venner and Co., where he was responsible for meters and time-switches. In 1911 he persuaded Mr. R. F. S. Venner and Mr. R. G. Graseby to join him in establishing the firm of Venner Time Switches, and from the beginning the three men formed its directorate. For some years during and after the First World War he was, in addition to his connection with Venner Time Switches, a director of the Jackson Electric Stove Co. and of Tok Switches Ltd. He retired from the position of Managing Director of Venner Time Switches in 1940, although he did not sever his connection with the Board till three years later. Mr. Sharp was then living in Somerset, but later he sought the sun of South Africa for the benefit of his health.

During the 1914–18 War, he at first served as a volunteer in Lloyd George's organization for munition supply, and from 1916 onwards he served in the army in Great Britain and France with the rank of Captain.

Mr. Sharp was a regular subscriber to The Institution's Benevolent Fund and gave generously to the Homes Fund on its establishment. He was also a generous contributor to, and the hardest of workers for, the Electrical Industries Benevolent Association, of which he was a Past-President. His forethought was very largely responsible for developing the scope of the Association in the inter-war years, and his enthusiasm was an inspiration to others to help in this extension.

In masonic circles Mr. Sharp was widely known; he was a Past Grand Standard Bearer of England and held other high masonic degrees. In the Second World War he was a volunteer Traders' Salvage Officer in Taunton, and gave service in other activities that ranged from National Savings to A.R.P., it being typical of the man that he would turn his hand to any job which had to be done, however humble.

His hobbies were making friends, reading and travelling, and he indulged them all richly. He was erudite and had a deep well of interesting and useful knowledge and anecdotes on which to draw; albeit he was no pedant and had a delightful way of explaining things in a simple and ever entertaining manner.

Though he always seemed composed, he was a very active man and never left until to-morrow what could be done to-day. He was objective in all things, his mind was analytical, and he had a rare understanding of people; he could always see the other man's point of view. Thus he was able to set his course at the outset with greater sureness than many people and yet, if further information came his way later, he never hesitated to review his decisions. He had a keen sense of humour and was very welcome to any gathering of electrical engineers.

He joined The Institution as an Associate Member in 1909 and was elected a Member in 1933. He was a Member of Council from 1929 to 1932. Admitted to the Livery of the Worshipful Company of Clockmakers in 1926, he became Master of the Company in 1940–41. He was a Fellow of the British Horological Institute and a Fellow of the Royal Empire Society. H. S. F.

ALEXANDER SINCLAIR

Alexander Sinclair, who died on the 1st March, 1955, after an emergency operation, was born on the 28th May, 1893. He was educated at Rothesay School from 1898 to 1909, and in 1910 he joined the Craigpark Electric Cable Co., with which he remained for the rest of his life. After serving in various departments of the business, he was appointed Secretary in 1925, and held this position until 1948. In 1923 he passed the final examination of the Association of Certified Accountants. In 1939 he was appointed General Manager of the company—as he still was at the time of his death—and he was elected to the Board in 1948.

Mr. Sinclair was a native of Glasgow, but for many years he had stayed in West Kilbride, a small west-coast town in Ayrshire, where he was a well-known figure. He is survived by his widow, a son and two daughters.

He was elected a Companion of The Institution in 1950. W. G. B.

HENRY GEORGE SOLOMON

Henry George Solomon, who died on the 19th March, 1955, after suffering ill health for several months, was born on the 1st April, 1872, in Melbourne, where he received his early education. From the age of 13 to 18

he continued his education in Hanover, Germany, and in 1892 he began his technical training at the Central Technical College, South Kensington. He was awarded a Works Premium of £50 and spent three years as an apprentice at Siemens Brothers, Woolwich. At the end of the course he obtained a post as a lecturer in mathematics and electrical design at the Northampton Polytechnic, and after two years in this position he was appointed Manager of the Meter Department of the Electrical Co., London. During this time he wrote three books, namely "Electricity Meters," "Electric Metering Practice" and "Domestic Electric Heating."

With a view to obtaining experience in the supply industry he joined the Brompton and Kensington Electric Supply Co., and in 1903 he set up his own business as a consultant, specializing in electric furnaces, electricity meters, etc. In 1926 he was appointed Editor of *Science Abstracts* on the staff of The Institution and remained in this post until 1937, when he retired. He was retained as an abstractor to within a few months of his death, and in addition he acted as translator for the English edition of the *Bulletin Oerlikon*.

Henry Solomon was a quiet reserved man, probably owing largely to acute deafness, but he was always most willing to give a helping hand to younger engineers with technical problems. He kept abreast of electrical developments by constant visits to The Institution's library, where he was always glad to meet old friends among the members. He is survived by a sister, his wife having died nearly two years before him.

He joined The Institution as a Student in 1893 and was elected an Associate in 1895, an Associate Member in 1899 and a Member in 1915. H. J. N.

IAN THOMAS LANCASTER WHIPP

Ian Thomas Lancaster Whipp, who died on the 8th February, 1955, after a shooting accident in Co. Clare, Ireland, was born on the 24th February, 1914, in Rochdale, Lancashire. He was the eldest of three sons of Mr. Frank Whipp, Member, the present Chairman and Managing Director of Whipp and Bourne, Ltd.

After receiving his education at Uppingham and Downing College, Cambridge, he entered the firm of Whipp and Bourne, Ltd. He spent several years gaining knowledge in the manufacture and testing of electrical switchgear in the works, and later he was appointed a Director of the company. Amongst his many activities for the company were those connected with the design of switchgear for H.M. ships, and the development of high-speed circuit-breakers.

Ian Whipp was a likeable character, full of good humour, and courteous to everyone he met; he will be sadly missed by all who knew him. He leaves one son, having lost his wife in July, 1953, after a long illness.

He joined The Institution as an Associate Member in 1943 and was elected a Member in 1951. H. H.

WILLIAM JOHN HANVEY WOOD

William John Hanvey Wood, who died on the 2nd March, 1955, was born on the 10th August, 1878, in Antwerp, Belgium, where his parents were then residing. He received his general education in Antwerp, his engineering education at the Crystal Palace School of Practical Engineering, London, and his practical training with the Cie Le Phoenix and the Cie Hydro-Électrique, Antwerp.

Mr. Wood returned to Great Britain in 1898 and entered municipal electrical service as a junior engineer with the Edinburgh Corporation; three years later he went to Bolton as Assistant Engineer, becoming Borough Electrical Engineer and Manager in 1913. As the Borough Electrical Engineer of Bolton he was directly responsible for the design and construction of the Back-o'-th'-Bank generating station. On the formation of the North Western Area District Industrial Council and the District Joint Board for the electricity supply industry in 1919, he represented on these two organizations a group of the largest electrical undertakings. He was appointed Chairman of the Engineering Committee of the South-East Lancashire Electricity Advisory Board in 1925. In 1927 he was appointed Engineer-in-Chief to the County of London Electric Supply Co., a position he held until his appointment as Joint General Manager and Director of the company. He was also a Director of the Kent Electric Power Co. and of the Bournemouth and Poole Electric Supply Co. until April, 1948, when the industry was nationalized. During this period he was responsible for the extensions to Barking power station, the Littlebrook "A" and "B" power stations in Kent, and the beginning of the construction of the Blackwall Point and Poole stations for the South Metropolitan Electric Light and Power Co. and the Bournemouth and Poole Electric Supply Co., respectively. After nationalization he became a part-time member of the London Electricity Board, from which he retired in December, 1953; he also accepted and retained until his death an appointment as Consultant to Merz and McLellan, with whom he had previously been closely associated.

Mr. Wood was a sound engineer with a varied experience, and he had great personal charm which, combined with a capacity for leadership, promoted a feeling of loyalty and devotion in his staff and associates. He was a man of simple tastes whose principal hobby was gardening. He is survived by his wife, a son and a daughter.

Mr. Wood joined The Institution as an Associate Member in 1912 and was elected a Member in 1918. He served as Vice-Chairman of the North Western Centre in 1919–20, and subsequently on the Committee of this Centre. From 1934–37 he served as a Member of Council, and as a Vice-President in 1944–45. With Mr. Forbes Jackson he was joint author of a paper entitled "The Future of the Domestic Wiring Installation, Part 1—Immediate Developments," published in the *Journal* in 1943, for which the Swan Premium was awarded to the authors. He was also a Member of The Institution of Mechanical Engineers. W. D.

MONOGRAPHS AND PAPERS

published separately this month

Separate monographs and reprints of all papers published in the Proceedings are available at the price of 1s. 3d. each (post free). The inclusive charge for a copy of a paper allocated for reading at a meeting on separate publication and for a reprint of the paper and discussion (as republished in the Proceedings) is 2s. 6d. (post free). This charge is made whether or not the reprint is required, but a reprint alone costs 1s. 3d. as noted above. However, separate copies of a paper allocated for reading are supplied free of charge 10 days before the first meeting at which the paper is to be read, whether in London or in the provinces. If a reprint also is required, a remittance should accompany the request. Reprints of a paper being read at a meeting cannot be issued before the paper and discussion have appeared in the Proceedings, but they should preferably be ordered before or shortly after the paper has been read in London.

In an order, a monograph or a paper can be specified completely by the author's surname and the serial number of the paper. Those who wish to avoid making a separate payment for each monograph, paper, or reprint which they require can obtain books of voucher-labels, price 10s. each, containing 8 vouchers, on application to the Secretary.

A list of papers published in the June issue of Part A of the Proceedings appears under "Contents of the Current Issues of the Proceedings" on page 401, and the serial number of each paper and the month of publication of a digest in the Journal are included. Synopses of both monographs and papers which will be published separately before the next issue of the Journal appear below, and unless otherwise stated, their date of publication is the same as this issue of the Journal. The monographs will be republished in Part C of the Proceedings, and the relevant Part for the republication of a paper is given after the serial number of the paper.

MONOGRAPHS

H. K. MESSERLE, M.Eng.Sc., B.E.E., and R. W. BRUCK, B.Sc., B.E.

Steady-State Stability of Synchronous Generators as affected by Regulators and Governors

MONOGRAPH No. 134 S

Voltage and power-angle regulation can be used to improve the steady-state stability of synchronous alternators, whereas speed governors and tie-line power controllers often introduce instability.

In the monograph methods of determining the effects of voltage and angle regulation on the steady-state stability limit are discussed, and they are extended to allow for the control of the prime-mover torque by means of governors and power controllers. The machine analysis is based on the general equations for synchronous machines. Results, as obtained for typical alternators, are presented in the form of stability contour diagrams, which are very convenient for design purposes, since optimum control parameters can be read off directly.

A digest of the monograph will be published in Part A of the *Proceedings*.

M. E. ZEIN EL-DINE, Ph.D., and H. TROPPER, Ph.D.

The Electric Strength of Transformer Oil

MONOGRAPH No. 135 S

The monograph gives results of electric breakdown tests on transformer oil, made with direct and alternating voltages, and with impulses of different durations. The dried oil used in these tests was filtered and carefully degassed in a closed test apparatus which incorporated the test cell. The oil treated in this way was tested with uniform and non-uniform electrode configurations, and a number of factors which influence the electric strength of the treated oil were examined.

With the electric strength of the treated oil as a reference, the effect on its value was examined when a number of different impurities were added to the treated oil.

Finally, a theory of the electric breakdown of this type of liquid is suggested which conforms to the experimental observations reasonably well.

A digest of the monograph will be published in Part A of the *Proceedings*.

MISS L. J. SLATER, M.A., Ph.D.

A Short Table of the Laguerre Polynomials

MONOGRAPH No. 136

The monograph gives a Table of the Laguerre polynomials $L_n(x)$ referred to in a recent monograph by D. G. Lampard [*Proceedings I.E.E.*, Monograph No. 104 R, August 1954 (**102** C, p. 35)]. Notes on the calculation of the Table are included.

E. G. C. BURT, B.Sc., and O. H. LANGE, Dr. Rer Nat.

Function Generators based on Linear Interpolation with Applications to Analogue Computing

MONOGRAPH No. 137 M

The use of function generators in electronic analogue computing and simulation greatly extends the range of problems which can be solved by these methods. The monograph presents a technique in which diode units are used to approximate to the functions by linear interpolation. It is shown that the method can be extended to deal with a wide class of functions, including multi-variate functions.

Analogue multiplication and division are discussed as particular cases of function generators, and formulae for the general function are developed. The monograph gives the results of an experimental generator for $\sin x$ in the range $-\pi < x < \pi$, in which the error is about 1% of the maximum output.

A digest of the monograph will be published in Part B of the *Proceedings*.

R. A. BAILEY, B.Sc., Ph.D.

A Resonant-Cavity Torque-Operated Wattmeter for Microwave Power

MONOGRAPH No. 138 M

The monograph describes a sensitive method of microwave power measurement which makes use of the mechanical

force exerted by the electromagnetic field on a small vane in a resonant cavity. It is shown that the force on the vane is a simple function of the Q-factor of the cavity, the power absorbed in it, and the perturbation of its resonant frequency caused by the vane. The results of a comparison of an experimental wattmeter based on this principle and a water calorimeter are given, and the requirements of a practical instrument are discussed.

A digest of the monograph will be published in Part B of the *Proceedings*.

PAPERS

S. E. HUNT, D. P. R. PETRIE, K. FIRTH and A. J. TROTT

An Electrostatic Analyser for the Absolute Measurement of Proton Energies and the Establishment of Fixed Points on the High-Voltage Scale

PAPER No. 1840 M; PART B

An electrostatic analyser for measuring the energy of proton beams from an electrostatic generator is described. The energy measurements are absolute and are referred finally to the voltage of thermostatically controlled standard cells. The angle of deflection, 63·2°, was chosen to focus a parallel incident beam on to a fine exit slit. Target currents of over 20 μA were thus obtained with an energy resolution of 1 200.

The energy of a proton beam producing the lowest strong resonance in the $F^{19}(p\alpha\gamma)O^{16}$ reaction was determined as 874·5 ± 0·9 keV (absolute), the width of the resonance at half maximum yield being 5·0 ± 1·0 keV. Resonances in the $Be^{9}(p\gamma)B^{10}$ reaction were found for proton energies of 2·567 ± 0·003 MeV, 1·083 7 ± 0·000 7 MeV and 989·5 ± 1·4 keV. The widths at half maximum yield of these resonances were 41 ± 3 keV, 3·8 ± 0·3 keV and 91 ± 5 keV respectively.

L. KNIGHT

An Electronic Calculator for Punched-Card Accountancy

PAPER No. 1867 M; PART B

The paper gives an example of the way in which electronic techniques are being harnessed to mechanize accountancy. The calculator described is a commercial product, designed for use with standard punched-card machines. It will read numbers off a card, calculate new information from these and punch the answers back into the same card, handling 100 cards per minute. It can add, subtract, multiply and divide, both in decimal and £ s. d. notation, and can be easily preset to perform any sequence of these operations. This sequence can be modified by special instructions on the card or as the result of a step in the calculation. Facilities exist for an automatic and thorough check that the correct answers have been punched into the card.

D. H. LUCAS, B.A., and P. E. PEPLOW, B.Sc.

The Measurement of Steam Temperatures in Power Stations

PAPER No. 1872 S; PART A

The sources of error in steam-temperature measurement are considered theoretically and the results given in a form suitable for application to practical cases. Confirmatory experimental work is described.

SOME RECENT BOOKS

JOHN DIEBOLD

AUTOMATION: THE ADVENT OF THE AUTOMATIC FACTORY

NEW YORK: VAN NOSTRAND. 190 PP. 22s. 6D.

FRANK G. WOOLLARD

PRINCIPLES OF MASS AND FLOW PRODUCTION

ILIFFE. 195 PP. 25s.

It is now some years since Americans started talking excitedly about the possibilities of automatic factories, and recently the subject has acquired prominence in the British popular Press. No one can doubt that the time is rapidly approaching when the completely automatic factory will be possible. It is Mr. Diebold's object to tell the top management and senior executives of industry what has already been achieved and what may be expected in the near future. His book is the result of a study carried out at the Harvard Business School and covers the whole gamut of operations which must be automatized in a completely automatic factory. He does not give any technical detail but describes, in general terms, systems that have already been in operation. Since he gives the names of the organizations which have developed and which are using such systems, his book will be of great value to those who wish to investigate what has already been achieved.

In the last chapter but one he discusses the effect that "automation" (a useful word invented by Mr. Diebold) will have on business in general, particularly on the small firm. Unfortunately he has insufficient factual information to allow him to reach any conclusions. The last chapter is concerned with social and economic effects; Mr. Diebold concludes that even in America automatic factories are most unlikely to result in any major increase in unemployment. He bases this on the fact that less than 25% of the total labour force of the United States (excluding armed forces) were in 1950 employed in the manufacturing industries. Automation will be possible only in some of the manufacturing industries,

and in any case can be introduced at only a relatively low rate since it always requires capital expenditure. Thus, though its introduction will result in some redistribution of labour, there should be no redundancy. Clearly this must apply even more certainly in Britain, where at present we have over-full employment, and where reduction of labour costs is always likely to increase the demand for a product provided the saving is not swallowed up in capital cost.

Mr. Woollard, on the other hand, is a practical engineer with wide experience of mass and flow production, having pioneered these techniques in the nineteen-twenties for Morris Motors. His book is primarily concerned, not with automation and the automatic factory, but with the great advantages that come of flow production and the means by which it can be achieved. He lays down 18 principles on which successful flow production must be based and then by means of examples shows how these principles may be put into effect.

Like Mr. Diebold he starts with a short history of flow production, but whereas he traces mass production back to machinery for making pulley blocks for the Navy, conceived by Brunel in 1802 (in full production in 1809 with an annual output of 130 000 blocks and dead-eyes), Mr. Diebold begins with the automatic continuous-flow flour mill, set up near Philadelphia by Oliver Evans in 1784, i.e. before the onset of the Industrial Revolution in Britain. Mr. Diebold also recalls that Joseph Marie Jacquard exhibited the first automatic loom, controlled by punched paper cards, in Paris in 1801, and that by 1812 about 11 000 of these looms were operating in France alone. In 1833 the naval victualling office had mechanized the manufacture of biscuits, and about that time Charles Babbage was designing his automatic calculating machine. Thus, automation and flow production, far from being upstarts in the engineering field, are as venerable as most other branches.

Automatic machinery has been in use in many industries for a very long time, but this does not necessarily lead to flow production and is a far cry from the automatic factory. The grouping together of automatic machines with automatic transfer between them is the next stage in the development of the automatic factory, and for this to be successful the principles of flow production must be observed. The pioneers in this field have been the A. O. Smith Corporation of America, who started to design a completely automatic plant for making motor-vehicle chassis in 1915, and have developed an automatic plant for making large pipes, at a rate per day of 15 miles of pipe weighing 3 000 tons. Both of these are described by Mr. Woollard. It is significant that the plant for making chassis is sufficiently flexible to make it economical to alter its arrangement for an order of about 60 000 frames.

Like Mr. Diebold, Mr. Woollard ends by considering the effect of flow production and the automatic factory on human relations. In fact, throughout the whole of his book Mr. Woollard clearly has in mind the well-being of the factory workers. These books, the one for the higher executive, the other for the engineer, show that the automatic factory in which the drudgery at present carried out by man would be performed by machines is for many products feasible, if not yet economic. The object of this must be to give more time and opportunity for the exercise of judgment, which should result in much more economic manufacture and a general raising of the standard of living. Both Mr. Diebold and Mr. Woollard reach the conclusion that the advent of the automatic factory should not result in any unemployment, but should be to the advantage of all.

These are books which ought to be read by all those who are considering automation, whether from the practical production standpoint or from that of the trade unions and sociologists.

J. ZABORSZKY and **J. W. RITTENHOUSE**
ELECTRIC POWER TRANSMISSION
NEW YORK: THE RONALD PRESS. 686 PP. £3 10s.

Largely as a result of geographical conditions, much important pioneering work on long-distance electric-power transmission has been carried out in the United States, and several of the classic treatises on the subject have been written by American engineers. Although the development of power-transmission systems has been spectacular during the last few decades, the basic principles have not been extended greatly and it is therefore interesting to see how a new textbook differs from its predecessors.

The book opens with an introductory chapter on the basic design of a power system and the functions and types of transmission, sub-transmission and distribution systems. The following chapters deal with the fundamental line constants (inductance, resistance and capacitance); corona; constants of underground cables; the performance of transmission lines and power systems in the steady state; voltage regulation; load-frequency regulation; and power-system economics. The Appendix contains tables giving the characteristics, including current-carrying capacity, of copper, steel-cored aluminium and Copperweld overhead-line conductors, and underground cables up to 230 kV. It also includes a short survey of methods of solving simultaneous linear equations.

Much of the material has not previously been published in book form. This includes a description of the universal power-circle diagram (a single diagram for both sending and receiving ends), probability methods of assessing spare plant capacity, and load-frequency regulation.

The authors' claim that the book offers a complete and balanced treatise on the steady operation of transmission lines and power systems is largely justified. On the other hand there are some gaps. The insulation of power lines is not mentioned—a surprising omission in the reviewer's opinion. Radio interference is dismissed in half a page. This is a subject of rapidly increasing importance as a result of the development of radio services and the extension of overhead-line power systems. Information on the frequency-spectrum of power-line radio noise, and the attenuation of the noise with distance from the line, could have been included with advantage. Bundle conductors do not receive as much attention as their importance warrants. D.C. transmission is not mentioned, even from the theoretical point of view. In addition the book might have been brought more up to date on recent transmission developments. It is stated, for example, that "lines with voltages ranging from 315 to 400 kV are under construction or in advanced stages of design in the U.S.A., Sweden, France and Germany." In Sweden, 380 kV lines were actually in operation in 1952, two years before the date of publication of the book.

These minor deficiencies, however, do not appreciably detract from the value of the book, which should find an honoured place on the bookshelves of advanced students and transmission-line engineers.

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 20TH MAY, 1955

	No. of Contributors	£	s.	d.
£1 000 and over	6	6 000	0	0
£100 to <£1 000	29	6 386	3	0
£5 to <£100	737	8 246	16	10
£2 to <£5	1 796	5 016	19	7
Under £2	17 305	9 198	18	3
		£34 848	17	8

JUBILEE OF THE THERMIONIC VALVE AN INSTITUTION PUBLICATION

Profusely illustrated, printed entirely on art paper and bound in substantial semi-stiff covers, the Institution publication entitled "Thermionic Valves—the First Fifty Years" makes its appearance towards the end of this month. As already announced, this book contains the lectures delivered by Sir Edward Appleton, Professor G. W. O. Howe and Dr. J. Thomson at the Jubilee Meeting in November, 1954, together with brief descriptions of about 250 valves—from Fleming's diodes to travelling-wave tubes—which were gathered together for the occasion.

The size of the book is 76 pages, demy quarto, and its price (post free) is 9s. to the public, and 4s. to members of The Institution. The edition is limited, and orders should be sent to the Secretary without delay.

This reminder is addressed chiefly to power engineers—many communication and electronic engineers will no doubt have already ordered their copies.

ELECTIONS AND TRANSFERS

Particulars of 340 elections and 197 transfers approved by the Council will be found on page 399.

CONVENTION ON DIGITAL COMPUTER TECHNIQUES

9TH–13TH APRIL, 1956

The arrangements for this Convention include a formal Opening and Introductory Lecture in the evening of the 9th April, 1956, and on the following four days there will be sessions for the reading of general papers, with parallel sessions for specialists.

Papers accepted for the Convention will be published in advance, and the latest date for the receipt of manuscripts is the 30th September, 1955. Any author who wishes to offer a paper for the Convention should write, as soon as possible, to the Secretary of The Institution, giving the provisional title of the paper and the date by which the manuscript will be submitted, and asking for a copy of the "Handbook for Authors" if he does not already possess one.

HUNTING MOVEMENTS IN RAIL VEHICLES

COMPETITION ORGANIZED BY THE INTERNATIONAL UNION OF RAILWAYS

The International Union of Railways has allocated funds to encourage research on the hunting movements of railway vehicles.

Rail vehicles are subject to a parasitic movement over and above their principal movement, even when running on perfect track. This parasitic movement can develop in many degrees of freedom. Two components of this movement, that transverse to the centre line of the track and that rotational about a vertical axis, have adverse effects on stability and riding comfort. In general, the combination of these two components is called hunting.

The Union is organizing a competition for theoretical solutions to the problem of these hunting movements, with an example of the application of the method used to a simple design of vehicle. Existing experience should be considered in the solution, and competitors may use any published material. Any person or research organization may participate in the competition, and awards up to a total of 25 000 Dutch guilders (about £2 350) will be made to competitors who are judged to offer the best solutions leading to an improved understanding of the problem.

Those interested in this competition should apply for full information, before the 30th June, 1955, to the President of the Office for Research and Experiments, International Union of Railways, Moreelsepark 1, Utrecht, Holland.

PREVENTION OF TARNISHING OF SILVER, COPPER AND BRASS

The Chemical Research Laboratory has recently found that articles made of silver, copper and brass, when wrapped in jewellers' tissue paper impregnated with one of certain substances, do not tarnish during several months' storage in air containing some hydrogen sulphide. The impregnating substances which have been found effective include chlorophyll, tannins, copper chromate, copper phosphate, zinc chromate and lead nitrite.

It is probable that similar wrapping will be effective in preventing tarnish in industrial and urban atmospheres; possibly the mere inclusion of chlorophyll or other absorbent with articles stored in a confined space will also be effective.

This discovery may be of value to the electrical industry when there is prolonged storage of silver relay contacts, or of copper and brass parts which will ultimately be tin-dipped or soldered, provided they can be suitably wrapped or enclosed. It may also apply to enclosed relays and similar equipment during service. It seems less likely that it can be used where parts are stored in open bins, or for open equipment in service.

Trials of this technique in actual industrial atmospheres where tarnishing occurs rapidly will be of considerable interest. If such trials fulfil the promise of the laboratory tests, it may well be worth adapting storage conditions to make use of the method, and experimenting with its application to certain types of enclosed light-current equipment.

Further particulars may be obtained from the Department of Scientific and Industrial Research, Chemical Research Laboratory, Teddington, Middlesex.

THE JOURNAL REFERENCE SECTION *(pages 395-402)*

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*J. VAUGHAN HARRIES

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ISRAEL
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Hon. Secretary: N. YOUNG, 22 Foxton Avenue, Cullercoats, Northumberland.

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Elections and Transfers

The following elections and transfers approved by the Council are effective from the 31st March, 1955.

ELECTIONS

Graduates

ALEXANDER, Raymond James, B.Sc.
ASHTON, John Alfred, B.A.
BAKER, George Joseph, B.Sc.
BANKS, Edgar Roger, B.E.E.
BARLOW, William Lowbridge, B.Sc. (Eng.).
BOWLES, Donald Clive.
BOYLE, William, B.Sc.
BROGDEN, James.
BURRIDGE, Ronald William.
BURRIN, Eric Darvell, B.Sc.(Eng.).
CADDY, Gordon George.
CHANTREY, Philip, B.Eng.
CHOWNEY, Kenneth John.
DARWIN, George Pember, B.A.
DAWSON, David Gilmour, B.Sc.
DYKES, Malcolm Stanley, B.Sc.
DYSON, Sheila Mary, (Miss), B.Sc. Tech.
FOSKETT, Roger Durley, B.Sc.(Eng.).
GAUR, Jitendra Nath.
GIBSON, Eric Reginald.
GILES, Alan Robert Douglas.
GODFREY, John William Alexander, B.Sc.(Eng.).
GOOCH, Ronald Francis.
GOODFELLOW, Thomas Leslie, B.Sc.
GRIFFIN, Donald Ward, B.E.
HAMBLY, Dudley Lethbridge.
HAMLYN, Kenneth Edwin Charles.
HANSON, Jeffrey Roy, B.E.E., M.Eng.Sc.
HAYLETT, Horace Richard.
HELLEWELL, John Watkin.
HELYAR, John Aubrey.
JOHNSON, Maurice William, B E.
KILLIPS, Robert William.
KIRKPATRICK, Murray Thomas.
KURIJ, Frank, B.Sc.(Eng.).
LITTLE, Stephen James.
McLENNAN, Kenneth Grant.
McWHA, James.
MAVOR, John Osborne, B.A.
MICHAEL, Gareth Wyn.
NAYLOR, John Francis.
NECCI, John Roger.
NOTON, Arnold Roy Maxwell, B.Sc.
PHYSICK, Roy Joseph.
RAY, Boris.
RUSSELL, George Stanley.
SLOANE, Bernard Joseph.
SMITH, Raymond John.
SWANN, John Michael, B.Sc.(Eng.).
TAYLOR, John Rex, B.Sc.(Eng.).
WALSH, Leo Harvey.
WHALE, Anthony Victor, B.Sc.
WILLETT, Robin Rex.

Students

ALI, Osama Mohamed.
ALLAN, William James Wilson.
ANG, Pang Ee.
ARMSTRONG, Alan James.
ATKINSON, Peter.
BARBER, Reginald John.
BARRACLOUGH, Michael.
BARTON, Kenneth.
BILLINGE, Peter Louis.
BLOOMFIELD, John.
BURROW, Peter Andrew.
CARTER, Ronald Philip.
CATLOW, Fred.
CHATTERS, Kenneth Ernest.
CHILD, John David.
CLAYDON, John Bernard.
CODLING, John Anthony.
COLLIER, John Miles.
COLLINS, Brian Peter.
CONWAY, Alan Charles, B.Sc.
COTTON, Joseph.
CURTIS, Dudley.
DASGUPTA, Sunit.
DASS, Sham.
DEBOO, Gordon John.
DEMPSEY, Thomas Anthony.
DEMPSTER, Ian Alexander.
DEVONSHIRE, Clifford Joseph.
DILWORTH, Anthony John Nicholas.
DUNCAN, Norman James.
EMMERSON, Bruce William.
ERGATOUDIS, Themistoclis Panayiotou.
FARAZMAND, Bahman.
FRASER, Daniel Borland.
GANDER, John Raymond Henry.
GARCIA, Alan John.
GIBBS, Clive.
GILLESPIE, Ernest Fred Francis.
GILMOUR, Euan Crawford Falconer.
GOODGER, Michael.
GORDON, Kenneth Ian.
GRIFFIN, Donal Patrick.
GUERANDEL, Louis Paul Marie Jean.
GURJAR Arivind Gangadhar.
HALL, Eric.
HANCOCK, Alan John.
HARDING, Peter Frank.
HEARD, Derek Charles Edward.
HENRY, Colin John McKenzie.
HESLOP, Doris Alderson, (Miss), B.Sc.
HILLAS, Michael Joseph.
HUMPHREYS, John Harold.
IVES, Derek Edwin.
JACKSON, George Eric.
JONES, Cyril Lloyd.
JONES, David Lloyd.
JONES, John Francis.
JONES, Kathleen, (Miss).
JORDAN, Francis Anthony.
JULIEN, Kenneth Stephen.
KENTISH, Lionel.
KIRK, Geoffrey Thomas.
LAMB, Laurence James.
LANE, Kenneth Robert.
LAWLOR, Joseph Patrick.
LOGAN, Edward Alexander (Jnr.).
LOUFTE, John Claude.
LOWNDS, Roylance.
McMULLAN, Victor Jardine.
MACPHERSON, Colin.
MARTINDALE, John Walker.
MATLEY, Joseph Brian.
MEEKS, Edward Ernest.
MELLOR, David Ramsden.
MILES, Cyril John.
MOLLOY-VICKERS, John Anthony.
MORAGHAN, James Sylvester.
MOSES, Raymond.
NELSON, Brian.
NOBBS, Kenneth Harry.
NUTTALL, Leslie.
O'DONNELL, John Emanuel.
O'FARRELL, Patrick Sylvester.
PARE, Clifford Frederick.
PASCALI, Petros Photiou.
PEIRIS, Hennedige Jayarajah Chandrasiri.
PURI, Lalit Mohan.
RALPH, George.
RAMACHANDRA, Sinnathurai.
RAMANATHAN, Kaithakode Puthenvedu.
RASHID, Abdul.
RAYNER, Ronald Douglas.
REVELL, John Peter Charles.
RIGG, Harold.
ROBINSON, Ian Lovell.
ROGERS, Martin Richard Newsome.
SANDERSON, Frank Colin.
SCOTT, Frank Victor.
SCULLY, Cecil Raymond.
SHENTON, Colin George Arthur.
SINGH, Parduman.
SIVASUBRAMANIAM, Ponniah.
SMITH, David Richard.
SUKUL, Jagat Narayan.
TIVEY, Alastair Michael.
TSOI, Shiu Foo.
TYM, Aubrey James William.
VOSS, Walter Arthur Geoffrey.
WALKER, Ronald Brown.
WAY, David Douglas.
WELLEN, Peter Antony.
WHYATT, Francis Glyn.
WOODFIELD, John Western.

TRANSFERS

Student to Graduate

BANKS, Frank Henry Reginald.
BEADSMOORE, John Keith.
BROOKFIELD, John Windsor.
BROWN, Charles Alfred.
CRABBE, Herbert David, B.Sc.
ELLISON, James Bruce.
FISHER, Norman Eric, B.Sc.(Eng.).
GRAY, David Davidson.
GUNARY, Kenneth.
HAIGH, Gordon, B.Sc.(Eng.).
HAMPTON, Michael John.
HARRIS, Michael John, B.Sc.(Eng.).
HIELD, Michael Richard Arthur, B.Sc.(Eng.).
LILLICRAP, Terence William.
McNEILL, Gordon Victor.
MUIR, Alexander Brodie, B.Sc.
PARKS, Harry Reginald.
POPE, Peter James, B.Sc.
POWER, Samuel Robert Douglas, B.A.
SEPHTON, Robert Martland.
SLANEY, Brian Michael Arthur, B.Sc.(Eng.).
SOUTER, Alexander Murison, B.Sc.
STUTCHBURY, John Frederick, B.Sc.(Eng.).
TOMICA, Alojzy, B.Sc.(Eng.).
YOUNG, Arthur Philip, M.A.

The following elections and transfers approved by the Council are effective from the 1st April, 1955.

ELECTIONS

Associate Members

BOOTH, Jack Kenneth.
CHU, Shi Chong, B.Sc.(Eng.).
DUPLESSIS, Cornelis Barnard Moll, B.Sc., B.Sc.(Eng.).
FERGUSON, Roderick Neil McKillop.
FLEMING-WILLIAMS, Brian Clifford, B.Sc.
GIPPS, Louis Henry Fitzroy Pemberton.
HALL, Charles Godfrey.
HAND, Robert.
McCORMICK, Terence.
MISRA, Raj Pratap, B.Sc., M.E.E.
MORGAN, John Hiley.
NOBLE, Henry Royce, M.Eng., Ph.D.
O'CONNELL, Eric Francis.
SIMS, Edward James.
SOWMAN, Kenneth Barend.
STUART, Joseph Victor.
TAYLOR, Colin Stephen, B.E.
TAYLOR, George Carnegie Cheyne.
YOUNG, Victor Jay, A.B., M.S., Ph.D.

Associates

ANDREW, Harry Leathley.
ASHTHORPE, Albert Orrell Henry, Lt.-Cmdr.
FULFORD, Harold Frederick.
JOLLY, James Isaac.
KUBCZYNSKI, Boleslaw.
MUKERJEE, Amarendra Nath.
OSTERLOFF, Thomas.
PERYER, Norman William.
RICHARDSON, Robert Arthur Stanley.
ROBERTS, Frank Leslie.
STEPHAN, Emanuel.
THOMAS, Gordon Stuart.

TRANSFERS

Associate Member to Member

BROERSMA, Cornelis B., E.I.
DALLOW, James Claude.
DALTON, James.
EWEN, Alfred Whitelaw.
GILKS, Francis Richard.
GOZZARD, James, B.Sc.(Eng.).
HARDING, George Roland, T.D., B.A.
HENZELL, Maurice Peregrine.
HUNTER, Ian Wilson, B.Sc.
KING, Charles.
LAWLOR, James Butler Stopford.
PIERCE, John Douglas.
PLUMMER, Cyril Charles, B.Sc. (Eng.).
SANKEY, George Henry, B.Sc.(Eng.).
STREET, Walter George.
TROOST, Niels, B.Sc.(Eng.).
VENNER, Michael, B.Sc.(Eng.).

Graduate to Associate Member

ALEXANDER, Edward.
ARNOLD, Roy, B.Sc.Tech.
ATTWATER, Frederick Henry.
BAMFORTH, George.
BARNES, William Jack.
BARTON, David Henry.
BATTERSBY, Alan, B.Sc.Tech.
BEAUMONT, Philip Milton.
BELLIS, Randle John.
BELTON, Rex Cyril.
BIRCHALL, John Vernon Raymond, B.A.
BRIGGS, Arthur Hampton.
BUDEK, Jerzy, Dipl.Ing.
BURRELL, John Gill.
CAPLEN, Geoffrey John.
CARPENTER, Ronald Harry.
CHARIN, Leon Irving, B.Sc.(Eng.).
CHIPPERTON, John Norman.
COLLINS, John Henry.

Graduate to Associate Member (contd.)

COOPER, Clifford.
CRANSWICK, Cecil Arthur, B.Sc. (Eng.).
CROMPTON, Allan John Lister, B.Sc.(Eng.).
DAVIES, David Leighton, B.Sc.
FRENCH, Edward Martin, M.C., B.Sc.(Eng.).
FROOM, Jocelyn, B.Sc.(Eng.), B.Sc.
GARNHAM, Edward John Butcher.
GOLDRING, Anthony Gerard, B.Sc.Tech.
HELPS, Frederick George, B.Sc.Tech.
HIGGINS, Colin.
HINCH, Joseph Edward.
HODGES, Stanley Walter.
HOLLOWS, Wilfred.
HORN, Reginald Paul Suttle, M.Sc. (Eng.).
HOWARD, Rodney Percy.
INGAMELLS, Edward Howard.
JONES, George Henry.
JONES, John Frederick.
KINGSLAND, James Martin.
LAWRENCE, Laurence Alan James.
LILLEY, Kenneth Vernon Alexander.
LUSCOMBE, Graham Wallis, B.Sc. (Eng.).
MACAULAY, Ian, B.Sc.
McDERMOTT, Patrick Andrew.
McKEITH, George William.
MARVELL, Frank Joseph.
MASON, Jeffrey.
MAX, Peter Robert, B.Sc.(Eng.).
NICOLLS, Andrew Campbell, B.Sc.
ORMEROD, Geoffrey.
POLLARD, Brian Watson, M.A.
POULTON, Arthur John, B.Sc.(Eng.).
RICHMAN, Robert John.
ROBINS, George William.
ROBINSON, Arthur Alexander, M.A., Ph.D.
ROBINSON, Harold George Robert, B.Sc.(Eng.).
ROGER, Thomas Francis, B.Sc.
ROOTS, William Kesteven, B.Sc., A.B.
RUSSELL, Kenneth Foden.
SHARP, Aubrey Donald, B.Sc.
SINGLETON, Ray, B.Sc.Tech.
SMITH, Donald Cecil.
STEVENS, Paul Abiry, B.Sc.(Eng.).
STUBBS, Harry.
THOMPSON, Rex Johnston.
THORNLEY, Kenneth.
TIMMINS, Albany Robert, B.Sc.
TOWLE, Peter Edward Neville, B.Sc. (Eng.).
WALTON, Leonard Havelock.
WEIR, Colin Greenwood, M.S., B.Sc.
WILKINSON, Wilfred Trevor.
WOOD, Kenneth, B.Sc.(Eng.).

Student to Associate Member

AINSWORTH, John Desmond, B.Sc. (Eng.).
ANDREWS, Frank.
GREENWOOD, James Dennis, B.Sc. (Eng.).
KEALEY, Albert Anthony, B.Sc.
RIDER, Frank John.
SHELTON, William Thomas.
THOMPSON, Terence Peter Dudley, B.E.

Student to Associate

INGRAM, Clifford Anthony, M.A.

The following elections and transfers approved by the Council are effective from the 21st April, 1955.

ELECTIONS

Graduates

ACKLAND, Roy Albert.
ALTON, William Lightbody, B.Sc.
ASARE, Jacob Kwame, B.Sc.(Eng.).
BAYFIELD, Gerald Albert.
BRUCE, Kevin James, B.E.
BUXEY, Dinshaw Jamshedji.
CHAPMAN, Maurice John.
COLBOURNE, Robert Henry, B.Sc. (Eng.).
CORNISH, Basil William.
CUMMACK, John Bycroft.
DAVID, Michael John, B.Sc.(Eng.).
DAYAL, Maheshwar, B.A.
DELAMER, Fitzherbert Peter, B.E.
DEMBECKI, John Adam.
DEUTROM, Vyvian Frederick Cecil.
DIFFORD, Douglas Arthur.
D'URBAN, Gerald William.
ELAHI, Shaukat.
EVERITT, Derek Percy.
FARR, Brian Charles.
FROGGATT, Dennis Gordon, B.Sc.
GEER, Peter Kenneth.
HEPTINSTALL, Arthur.
HODGE, Cooper.
HOLT, Alan George James.
JACKSON, Frank Walton.
JOHNSON, Donald Archibald Harvey, M.Sc.
JUMP, Kenneth.
KIDD, Robert Guy, B.Sc.(Eng.).
KING, Peter William.
LYNES, John Alexander, B.Sc.(Eng.).
McCULLY, Alfred Donald.
MacDONALD, Roderick Duncan, M.Sc.
MACLEOD, Malcolm Keith, B.Sc.
MacPHERSON, Gordon.
MALLETT, Ian James.
MORGAN, Bernard William.
OLAFSSON, Sverrir Sigurdur, B.Sc.
PETLEY, Douglas Charles.
PHILLIPS, John.
RACKHAM, Harold.
RIPPON, Kenneth Philip, B.A.
ROBERTSON, David.
ROBERTSON, Maurice.
SAYERS, Brian, B.Sc.Tech.
SCHOLES, Charles.
SHIPCHANDLER, Jaffer Yahyabhai.
TYASS, Aubrey Leonard.
VAN LOO, Pieter.
WALES, Robert Alistair McFarlane.
WILLIAMS, Robert John.
WILLSON, Stanley Russell, B.Sc. (Eng.).

Students

ABDULCADER, Ismalebbai Mohamed.
ANSARI, Rafique Ahmad.
ARMSTRONG, Alan Edward.
ASHLEY, Sidney Lewis.
ATKINS, Peter Brian.
AYE, Maung Maung.
BHALLA, Krishan Kumar.
BLAKE, Bond Michael.
BOWLER, Peter Ridgeway.
BRADLEY, David Nicholas.
BRIGHTY, Paul Francis John.
BURGESS, Peter William Ewan.
BURN, Robert Anthony Bulman.
BURNLEY, Leslie.
BUTLER, David McLean.
CAIRD, John Aitchison.
CARTER, Gerald William.
CASTEL, Brian Dennis.
CHEN, Eyson Chih Yao.
CHRISTMAS, John Francis.
CRECRAFT, David Ian.
DIAMOND, Robert Lindsay.
DIXON, John Francis.
DOBSON, Geoffrey.
DRAPER, Stanley William.
DUFF, Alan John.
DUTTA, Moni Charan.
FERNANDO, Gintotage Thompson.
FLYNN, John Barrie.
FORFOD, Thorleif Ragnar.
FRANGOU, Takis Antonios.
GOGERLY, Peter Robin.
GOODCHILD, Albert David John.
GOODENOUGH, Paul Douglas.
GOODLEY, Roger William, B.Sc.
GRANT, Robert Edward.
GROGAN, Kenneth Joseph.
GURJAR, Vinayak Pandurang.
HACKER, Malcolm Frederick.
HARDISTY, Keith Abbott Manning.
HAROLD, Leslie John.
HARVEY, Peter John.
HEALD, Wyndham Haldane, B.Sc.
HODA, Mohammad Masroorul.
HOLT, Roy Kenyon.
HULLS, Patrick John.
HUXLEY, Raymond Peter.
JOHNSON, Clifford.
KEMHADJIAN, Henry.
KING, Michael Geoffrey.
KIRKMAN, David.
KUNDU, Rabindra Mohan.
LANCASTER, Kenneth.
LEWIS, Thomas.
LOWE, Peter David.
MacKENZIE, Donald.
MINSHULL, John Francis.
MINTA, Samuel Agyei.
MORFIELD, Raymond Edward.
MORTON, Donald Frank.
NICOL, Robert William.
OBODAI, Emanuel Albert Kwaku.
OSTLER, Richard Ian.
OWEN, David Guy.
PETRIE, Colin Louden.
PRESS, Neil Francis.
ROBERTS, John.
ROBERTSON, Ronald James.
ROBSON, Colling Frank.
SALKELD, John Geoffrey.
SAMPSON, Richard Harold.
SETTLE, Bruce.
SEWELL, John Michael.
SHARMA, Jai Dev.
SHAW, Derek.
SHIPCHANDLER, Tyeb Mohsinbhoy.
SMITH, Derek.
SOOD, Satish Chandar.
SREENIVAS, Chikkaballabur Krishnasami.
STEELE, John Archer.
STEPHENSON, John Robert.
STEWART, Jeremy Ian.
THELWELL, Michael Joseph.
THOMPSON, Terrence Edward.
VASHIST, Ravikumar Shankardutt.
VENN, Albert William John.
WALKER, William Neil.
WALMSLEY, Bruno Joseph, B.Sc.
WILTSHIRE, Trevor John.
WITHAMS, Kenia Frederick Leonard.
WRAY, Arthur Henry.

TRANSFERS

Student to Graduate

ALLKINS, Donald Arthur.
BAKER, David Keith, Pilot Officer, B.Sc.(Eng.).
BALL, Frank Wallace.
BARNES, Peter McConnell.
BARTON, Alun.
BELGRAVE, Geoffrey Raymond.
BRENNAN, John Lewis, B.Sc.
BRITTEN, Donald Barrie.
BROWN, Denis Gordon.
BROWNLEE, Raymond John.
CAMPBELL, Walter Gardner, B.Sc.
CANNINGS, Frederick George.
CASSAR, Alfred George.
CHEVERTON, John Stuart, B.Sc. (Eng.).
CLOSE, William Edwin.
COOPER, Bernard John, B.Sc.(Eng.).
CRAIG, Duncan Robertson.
CRUST, Trevor James.
DAVIES, Frank.
DAWSON, Brian Leedham.
DEBNEY, Ivor Kenneth, B.Sc.Tech.
FAY, Eugene.
FRAY, Richard Patton.
GRAVER, Leonard John.
GRINSTEAD, Charles Peter.
HATFIELD, John Rawson, B.Sc. (Eng.).
HESTER, Geoffrey William.
HOLMES, Edward John, B.Sc.(Eng.).
HORSELL, Geoffrey Brian.
HUNT, William Alan.
INNS, John Michael Henry.
JEFFREY, Thomas Patrick, B.Sc. (Eng.).
JONES, Roger James.
LECHOWICZ, Stanislaw.
McATACKNEY, Joseph Gerard.
McCOOK, Patricia Joan, (Mrs.).
MacMURRAY, Charles Henry.
McPHERSON, Gordon Thomas.
MARTIN, Noel Stewart.
MILLINGTON, Kenneth.
NAKHLA, Nassef Latif, B.Sc.(Eng.).
NOWOTNY, Jerzy, B.Sc.(Eng.).
OAKLEY, John Richard.
OSBORNE, Ralph Irving.
OWEN, John Edward, Capt., R.E.M.E.
PARFITT, Everard Horace.
PARKER, Gilbert Edward, Flt.-Lt., R.A.F., B.Sc.
PAVEY, Colin Francis.
PEACE, John Graham, B.Sc.
PENHALL, Brian William George.
PIETTE, Ivon Ronald, B.Sc.(Eng.).
RAJAPAKSA, Don Shelton Ratnavibusena.
RIGBY, Geoffrey Arthur, B.Sc.(Eng.).
ROBERTS, Arthur Edward.
ROBERTS, Mervyn Taft, B.Sc.(Eng.).
ROBINSON, David Grisdale.
SARTAIN, Rex Thomas.
SAUNDERS, James Ernest.
SAVUL, Mohd Anwar.
SIMPSON, Christopher Paul.
SINGH, Patwant.
SIVATHASAN, Thambiah.
SKURR, John Alfred.
SMITH, Kevan Lyall.
SOMERVILLE, William Murray.
STAPLETON, Michael William.
STEELEY, Douglas Nigel.
STEPHENSON, Denis.
STUART, Robert Malcolm, B.Sc. (Eng.).
THOMPSON, Michael.
WATSON, Alexander Smith, B.Sc. (Eng.).
WHITE, Peter Albert, Pilot Officer, R.A.F., B.Sc.(Eng.).
WHITING, William George.
WILLIAMS, Donald Newton.
WOOD, James Gladstone Stewart.
WOOD, Peter Graeme.
YEH, Show Kun, B.E.E.
ZEEDERBERG, Lionel Brandon B.Sc.(Eng.).

Forthcoming Events

JUNE

25	*Saturday*	Radio Section Summer Visit to Rugby

SEPTEMBER

8	*Thursday to*	Supply Section Summer Visit to Holland
12	*Monday*	

Contents of the Current Issues of the Proceedings

DATE OF JOURNAL DIGEST OR SPECIAL ARTICLE

PART A. POWER ENGINEERING (JUNE 1955)

Digest not yet published — E. B. FRANKLIN. **Sealed Transformers** (PAPER No. 1674 S, JUNE 1954)

G. F. KENNEDY, M.A., M.I.MECH.E., AND P. H. MARGEN, B.SC.(ENG.). *March 1955* — **The Economic Selection of Cooling Towers for Generating Stations** (PAPER No. 1706 S, SEPTEMBER 1954)

P. H. MARGEN, B.SC.(ENG.). *March 1955* — **The Application of Friction/Heat-Transfer Correlations to Cooling-Tower Design** (PAPER No. 1705 S, AUGUST 1954)

Discussion on **Alternating-Current-Instrument Testing Equipment** before the North-Eastern Radio and Measurements Group

Special article not yet published — T. G. N. HALDANE, M.A., M.I.C.E., AND P. L. BLACKSTONE, T.D., M.A. **Problems of Hydro-Electric Design in Mixed Thermal–Hydro-Electric Systems** (PAPER No. 1749 S, NOVEMBER 1954)

Discussion on **Service Experience of the Effect of Corrosion on Steel-Cored-Aluminium Overhead-Line Conductors** before the North-Western Supply Group

Å. RUSCK. Lecture on **High-Voltage Transmission Developments in Sweden** before the Supply Section

Digest not yet published — A. MANDL, D.SC.TECH. **Single-Phase 50 c/s A.C. Traction using a Rectifier** (PAPER No. 1788)

Digest not yet published — D. B. REAY, M.SC.(ENG.). **Distortion of Turbo-Alternator Rotor Windings through Thermal Stress** (PAPER No. 1813 S)

Written discussion on **The Propagation of Surge Voltages through High-Speed Turbo-Alternators with Single-Conductor Windings**

Written discussion on **The Transient Behaviour of Ladder Networks of the Type representing Transformer and Machine Windings**

April 1955 — H. W. WOLFF, B.SC., AND T. G. F. ATHERTON, B.A. **Design, Performance and Application of Miniature Circuit-Breakers** (PAPER No. 1745 U, DECEMBER 1954)

Discussion on **The Logical Approach to the Problems of Space Warming by Electricity** before the East Midland Centre, the North-Western Utilization Group, the Mersey and North Wales Centre, the Western Centre, the North Midland Utilization Group, the Southern Centre, the South-East Scotland Sub-Centre, the North Staffordshire Sub-Centre, the Northern Ireland Centre and the South-Western Sub-Centre

Discussion on **Inherent Current, Voltage and Speed Control in Dynamo-Electric Machinery** before the North-Western Utilization Group, a joint meeting with The Institution of Engineers, Australia, the South Midland Supply and Utilization Group, the Mersey and North Wales Centre, the Western Utilization Group and the East Midland Centre

Discussion on **The Testing and Specification of Bushings in Relation to Service Conditions** before the Southern Centre, the Western Centre, the North-Western Supply Group, the North-Eastern Centre, the North Midland Centre and the Northern Ireland Centre

Discussion on **Telemetering for System Operation** before the Mersey and North Wales Centre, the Western Centre and the East Midland Centre

Written discussion on **Magnetic Measurement of Mechanical Hardness**

Discussion on **Resistance Heating of Mild-Steel Containers at Power Frequencies** before the Sheffield Sub-Centre

Discussion on **The Royal Festival Hall: Electrical Installation** before the North Midland Utilization Group, the South Midland Supply and Utilization Group and the South-Western Sub-Centre

Digests of Institution Monographs:

P. HAMMOND, M.A. **Leakage Flux and Surface Polarity in Iron Ring Stampings** (MONOGRAPH No. 116, JANUARY 1955)

J. W. LYNN, M.SC. **The Tensor Equations of Electrical Machines** (MONOGRAPH No. 117 S, JANUARY 1955)

E. UHLMANN, DR-ING. **Alternating Voltage, Direct-Voltage Regulation Drop and Power Factor of Convertor Stations operating on A.C. Systems of Finite Short-Circuit Capacity** (MONOGRAPH No. 131 S, MAY 1955)

Contents of the Current Issues of the Proceedings *(contd.)*

DATE OF JOURNAL DIGEST OR SPECIAL ARTICLE

PART B. RADIO AND ELECTRONIC ENGINEERING (MAY 1955)

M. E. HAINE, M.SC., F.INST.P., AND M. W. JERVIS, M.SC.TECH.
March 1955 — **The Use of an Electron Velocity Analyser to Stabilize a 50 kV Direct-Voltage Source to a Few Parts in a Million** (PAPER No. 1729 M, OCTOBER 1954)

M. W. JERVIS, M.SC.TECH.
March 1955 — **A Precision Direct-Current Stabilizer** (PAPER No. 1730 M, OCTOBER 1954)

H. PAGE, M.SC., AND G. D. MONTEATH, B.SC.
February 1955 — **The Vertical Radiation Patterns of Medium-Wave Broadcasting Aerials** (PAPER No. 1714 R, SEPTEMBER 1954)

Discussion on **A Short Modern Review of Fundamental Electromagnetic Theory** before the North-Western Centre

G. W. BOWDLER, M.SC.
March 1955 — **An Attracted-Disc Absolute Voltmeter** (PAPER No. 1675 M, JULY 1954)

Written discussion on **Experimental Equipment and Techniques for a Study of Millimetre-Wave Propagation**

Discussion on **An Investigation of the Characteristics of Cylindrical Surface Waves and Surface Waves** before the North-Eastern Radio and Measurements Group

PROFESSOR H. E. M. BARLOW, PH.D., B.SC.(ENG.), AND A. E. KARBOWIAK, PH.D.
Digest not yet published — **An Experimental Investigation of Axial Cylindrical Surface Waves supported by Capacitive Surfaces** (PAPER No. 1786R)

H. McG. ROSS, M.A.
March 1955 — **Equipment of Instrumental Accuracy for Recording and Reproduction of Electrical Signals, using Cinematographic Film** (PAPER No. 1696 M, AUGUST 1954)

E. G. ROWE, M.SC., P. WELCH AND W. W. WRIGHT, B.SC.
Digest not yet published — **Thermionic Valves of Improved Quality for Government and Industrial Purposes** (PAPER No. 1740 R, DECEMBER 1954)

W. W. H. CLARKE, PH.D., B.SC., AND R. F. NIKKEL, M.A.SC., B.A.SC.
Digest not yet published — **Mean Frequency Determination of Narrow-Band Noise Spectra** (PAPER No. 1836 M)

R. F. SAXE, PH.D.
Digest not yet published — **Automatic Control and Display in Impulse Testing** (PAPER No. 1839 M)

R. F. B. SPEED, B.A.
Digest not yet published — **A 24-Channel Pulse-Time Modulation System** (PAPER No. 1812 R)

G. D. MONTEATH, B.SC.
Digest not yet published — **Coupled Transmission Lines as Symmetrical Directional Couplers** (PAPER No. 1833 R)

Digests of Institution Monographs:

D. B. BRICK, PH.D., S.M., A.B.
The Radiation of a Hertzian Dipole over a Coated Conductor (MONOGRAPH No. 113 R, DECEMBER 1954)

T. W. STRAKER, M.SC., PH.D.
The Ionospheric Propagation of Radio Waves of Frequency 16 kc/s over Short Distances (MONOGRAPH No. 114 R, JANUARY 1955)

F. HORNER, M.SC.
A Table of a Function used in Radio-Propagation Theory (MONOGRAPH No. 115 R, JANUARY 1955)

PART C. MONOGRAPHS (MARCH 1955)

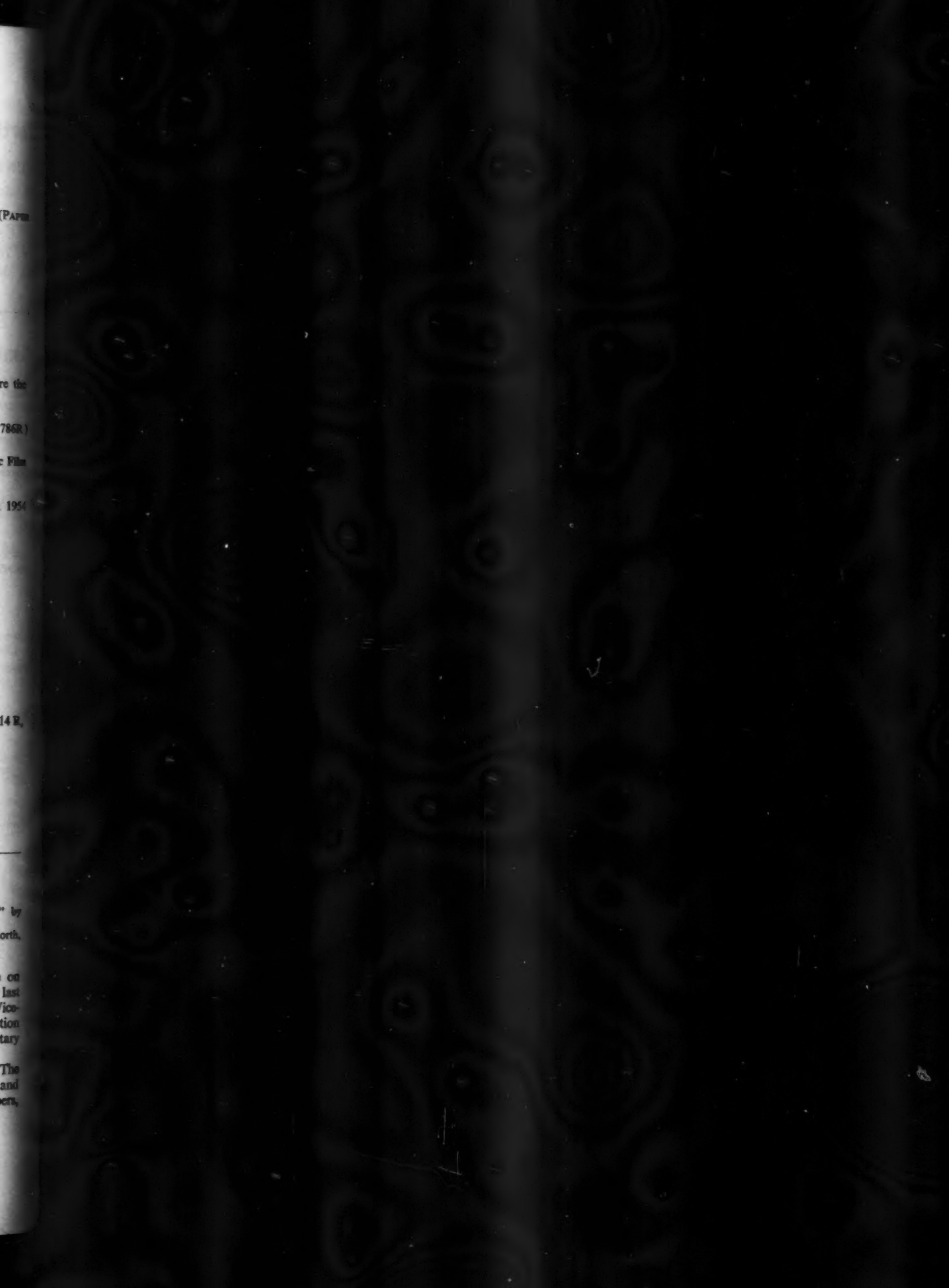
See March *Journal*, page 208.

Students' Quarterly Journal: 100th Issue

The June issue of the *Students' Quarterly Journal* will be the 100th, and, as befits such an occasion, there will be a number of special features. There are greetings from the President and a note on Mr. Reyner, who has edited the *S.Q.J.* since its beginning 25 years ago. There is a page of "vital statistics" showing the growth of students' activities, and the changes in the size and contents of the *S.Q.J.* over that period.

In addition there are abstracts of seven students' papers, whose titles and authors are:

"The Development of 50 c/s Traction in France," by E. J. Davies, B.Sc.
"Astronomy," by T. W. James.
"Carrier Telephony Commissioning in Italy," by P. Tyler and D. B. McRobert.
"An Application of Ultrasonics," by W. W. Wilson, B.Sc.
"The Operation and Routine Testing of Vision Transmitters," by A. Brown.
"The Design of Power-Station Auxiliary Systems," by R. B. Haworth, B.Sc.
"Electricity Applied to Oil Production," by G. Gascoigne.

Among the remaining items is an illustrated article on the London Students' Section Conversazione held last February; one photograph shows the Chairman, Vice-Chairman, Secretary and other members of the Section Committee for 1904–5 with the Chairman and Secretary for 1954–55.

The *Students' Quarterly Journal* is available from The Institution, price 3*s.* 0*d.* per issue, post free (Students and Graduates not over 28 years of age, free. Other members, 1*s.* 6*d.*).